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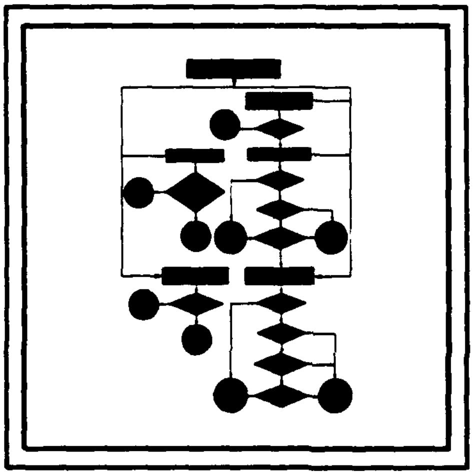
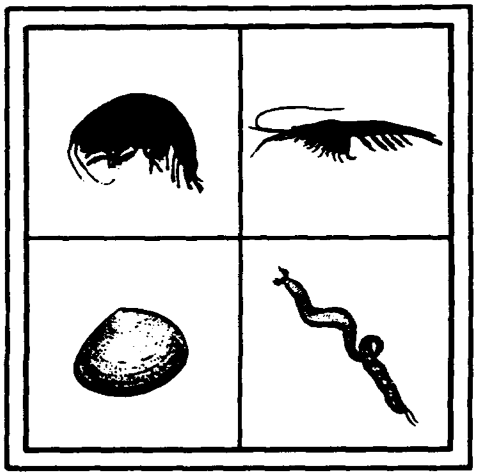
U.S. Army Corps
Of Engineers

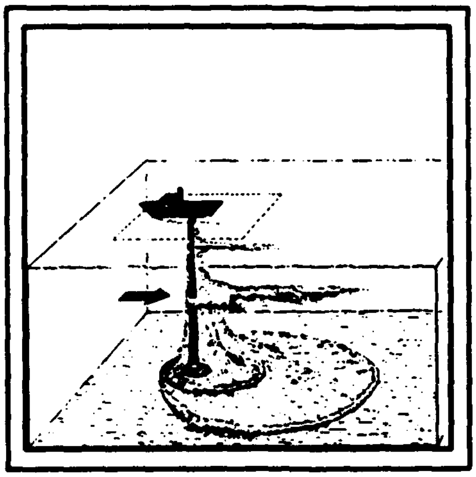
Evaluation Of Dredged Material Proposed For Ocean Disposal

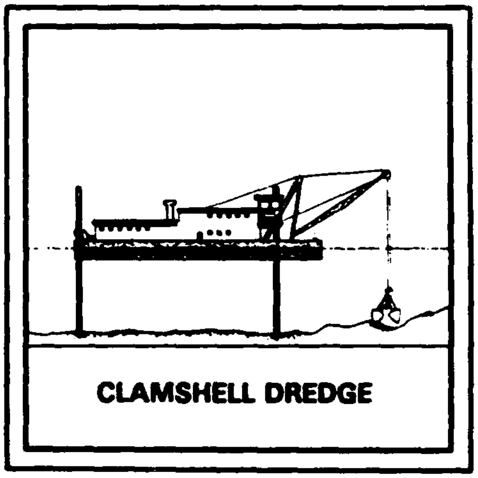
2

Testing Manual









United States
Army Corps of Engineers

Transmittal of the February 1991 Testing Manual

"Evaluation of Dredged Material Proposed For Ocean Disposal - Testing Manual"

In 1977, the US Environmental Protection Agency (EPA) and the US Army Corps of Engineers (USACE) published the testing manual titled "Ecological Evaluation of Proposed Discharge of Dredged Material Into Ocean Waters" (commonly referred to as the "Green Book" or "testing manual"). This national manual is used to determine the suitability of dredged materials for ocean disposal based upon the biological testing requirements of the 1977 Ocean Dumping Regulations (40 CFR 220-228).

Development of the Revised Testing Manual

Since 1977, the EPA and USACE have been improving the methods in the 1977 testing manual and in 1990 published a revised draft testing manual for public comment. A Notice of Availability was published in the Federal Register on March 7, 1990, announcing the availability of the document for review, and a public meeting to be held in Washington, D.C., on April 2, 1990, to discuss the manual and take comments. EPA and the USACE conducted the April 2, 1990, meeting in Washington, D.C., and held regional training sessions during 1990 in: Narragansett, RI; Gulf Breeze, FL; Vicksburg, MS; Newport, OR; San Francisco, CA; and, Washington, DC, to discuss the manual and take comment. Over 2,000 copies of the draft testing manual were printed and distributed. EPA and USACE have used the comments received on the 1990 Draft manual to develop this 1991 revised national testing manual entitled "Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual".

The 1990 Draft Testing Manual was reviewed in detail by all the EPA Regions and USACE Districts, other Federal Agencies, the public, Port Authorities, and various interest groups. All comments were taken into careful consideration in development of this final document and the time and effort expended by the reviewers was greatly appreciated. This 1991 revised manual contains many improvements over the 1977 manual. The revised manual is structured to be more easily interpreted than the 1977 manual and technical procedures have been revised to better represent realistic marine organism exposure to contaminants in dredged material. Other technical improvements in the manual

will enhance our ability to draw meaningful, technically sound conclusions regarding the suitability of dredged material for ocean disposal.

Implementation Schedule

This 1991 national manual replaces the 1977 manual in its entirety for implementation of the testing requirements of the 1977 Ocean Dumping Regulations. This manual should be used to make decisions regarding the suitability of dredged material for Ocean Dumping as of the date its availability is published in the Federal Register. It is not, however, expected that all EPA Regions and USACE Districts will be able to use it immediately, as time will be needed to develop local agreements/manuals which implement the guidance in this national manual and meet regional specific needs (such as the use of local species in biological tests and determination of contaminants of concern). It is therefore the intent of EPA and USACE that this revised testing manual will be phased in during the period between its announcement in the 1991 Federal Register and October 1, 1991. During this time, EPA Regions and USACE Districts will jointly develop and agree upon local implementation agreements/manuals based on this revised national manual, and begin using the tests and procedures in this manual to make ocean disposal decisions.

Implementation Process

The following process will be used to effect a smooth transition from use of the 1977 testing manual to the 1991 revised testing manual.

1. Projects or permits that begin prior to the completion of the local EPA/USACE agreement/manual for the area covered by the project may be evaluated using the 1977 manual and existing local guidance.

2. As soon as the local implementation agreement/manual, based upon this revised national manual, has been jointly developed and agreed upon by the local EPA Region and USACE District or Division, use of the new procedures and tests will begin.

3. In order to assist in a smooth transition from the 1977 to the 1991 national manual, a project or permit should be considered "begun" when EPA and the USACE have agreed upon a sampling and analysis plan to collect and analyze dredged material to determine its suitability for ocean disposal.

4. Once the local agreement/manual is approved by EPA and the USACE, sampling and analysis plans for new projects or permits should be based upon and evaluated by the procedures in the local implementation agreement/manual and this 1991 revised testing manual.

5. Any projects or permits approved before completion of the local agreements/manuals, based upon results of tests conducted under the 1977 testing manual, should be re-evaluated within 3 years of approval using this 1991 revised national testing manual and the local implementation agreement/manual.

Testing Manual Format and Future Revisions

In order to keep up with technical advances in the assessment of sediment contamination and potential impacts, this revised testing manual is published in loose leaf form. As advances are made and new procedures are agreed upon by EPA and USACE for use in evaluating dredged material, sections of this document will be revised or updated. When major revisions or new tests are appropriate, they will be prepared and the availability of the revised or new sections will be announced. In addition, everyone on the distribution list for this document will receive a set of the revisions.

Anyone wishing to be placed upon this mailing list should write to:

Green Book Mailing List
Care of: Ms. Billie Skinner
USACE, Waterways Experiment Station
EP-D
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Revised sections will be designed to totally replace or be inserted between existing sections and a new Table of Contents will accompany the revisions.

Tudor T. Davies
Director, Office of Marine and Estuarine Protection
US Environmental Protection Agency

APR 7 1991

Herbert H. Kennon
Acting Director of Civil Works
US Army Corps of Engineers

APR 14 1991

EVALUATION OF DREDGED MATERIAL PROPOSED FOR OCEAN DISPOSAL (TESTING MANUAL)

Prepared by

ENVIRONMENTAL PROTECTION AGENCY
Office of Marine and Estuarine Protection
Washington, DC

and

DEPARTMENT OF THE ARMY
United States Army Corps of Engineers
Washington, DC

February 1991

Prepared under

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

Appendices

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

PREFACE

According to Section 103 of Public Law 92-532 (the Marine Protection, Research, and Sanctuaries Act of 1972), any proposed dumping of dredged material into ocean waters must be evaluated through the use of criteria published by the Environmental Protection Agency (EPA) in Title 40 of the Code of Federal Regulations, Parts 220-228 (40 CFR 220-228). This testing guidance manual contains procedures applicable to the evaluation of potential contaminant-related environmental impact of the ocean disposal of dredged material. It will be periodically revised and updated as warranted by advances in regulatory practice and technical understanding. When this manual is approved by EPA and the United States Army Corps of Engineers (USACE), it will replace the July 1977 manual, *Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters,* which will no longer be applicable.

The manual was prepared by Battelle Ocean Sciences and EA Engineering, Science, and Technology, Inc., as part of a contract between Battelle Ocean Sciences and the EPA Office of Marine and Estuarine Protection (OMEP) (EPA Contract No. 68-C8-0105). The Work Assignment Manager was Mr. David Redford; the Work Assignment Leaders were Dr. Richard Peddicord, Ms. Nancy O'Mara, and Mr. Kurt Buchholz; the Technical Reviewers were Dr. Christine Werme, Dr. Carlton Hunt, and Mr. Brian Walls. Development of the manual was overseen by a group headed by Mr. Redford and composed of Mr. Craig Vogt and Mr. Barry Burgan of OMEP; Mr. Norman Rubinstein and Dr. John Gentile of the EPA Environmental Research Laboratory, Narragansett, RI; and Dr. Robert Engler, Dr. Thomas Wright, Dr. Michael Palermo, Dr. Thomas Dillon, Mr. David Mathis, Mr. Joe Wilson, and Mr. Kirk Stark of the USACE. The manual was written by scientists at Battelle Ocean Sciences and EA Engineering, Science, and Technology, Inc. Although many staff members contributed to the manual, lead authors contributed to each section, as follows.

Sections 1-7	Dr. Richard Peddicord
Section 8	Mr. John Williams and Dr. Richard Peddicord
Section 9	Dr. Grant Warner and Dr. Carlton Hunt
Section 10	Dr. R. Scott Carr and Dr. Richard Peddicord
Section 11	Dr. R. Scott Carr
Section 12	Dr. Richard Peddicord
Section 13	Dr. Carol Graves and Dr. Cary Tuckfield
Section 14	Ms. Patricia Royal
Appendix B	Dr. Billy Johnson, Dr. Michael Palermo, and Dr. Paul Schroeder

The assistance of Mr. Peter Washburn, Ms. Deanna Neubauer, and Ms. Barbara Greene in completing the manual is gratefully acknowledged.

Review of this manual was conducted by EPA through the Marine Operations Division of

the Office of Marine and Estuarine Protection and by the USACE through the Office of the Chief of Engineers and the Environmental Laboratory of the Waterways Experiment Station. Significant input on regional issues that have National relevance was received from EPA Region and USACE District staff and incorporated into the appropriate sections of this document.

Part I

GENERAL CONSIDERATIONS

1.0 INTRODUCTION

This manual, commonly referred to as the "Green Book," is an update of *Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters* (EPA/USACE, 1977). The manual contains technical guidance for determining the suitability of dredged material for ocean disposal through chemical, physical, and biological evaluations. The technical guidance is intended for use by dredging applicants, laboratory scientists, and regulators in evaluating dredged-material compliance with the United States Ocean Dumping Regulations.

Integral to the manual is a tiered-testing procedure for evaluating compliance with the limiting permissible concentration (LPC) as defined by the ocean-dumping regulations. The procedure comprises four levels (tiers) of increasing investigative intensity that generate information to assist in making ocean-disposal decisions. Tiers I and II utilize existing or easily acquired information and apply relatively inexpensive and rapid tests to predict environmental effects. Tiers III and IV contain biological evaluations that are more intensive and require field sampling, laboratory testing, and rigorous data analysis.

This manual provides National technical guidance for use in making LPC compliance determinations for proposed discharges of dredged material; it does not provide comprehensive guidance on other factors that should be considered during the sediment-evaluation process. Decision-making, involving the evaluation of regulations and local policies, site conditions, and project-specific management actions to limit environmental impacts, is addressed in other Environmental Protection Agency (EPA)/United States Army Corps of Engineers (USACE) guidance manuals.

1.1 BACKGROUND

Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Public Law 92-532, specifies that all proposed operations involving the transportation and dumping of dredged material into ocean waters have to be evaluated to determine the potential environmental impact of such activities. This is performed by the Secretary of the Army, using criteria developed by the Administrator of the EPA. In accordance with Section 103 of the MPRSA, the USACE is the permitting authority for dredged material, subject to EPA review. Environmental evaluations have to be in accordance with applicable criteria published in Title 40, Code of Federal Regulations, Parts 220-228 (40 CFR 220-228), hereafter referred to as *the*

regulations. Proposed ocean disposal of dredged material also has to comply with the permitting and dredging regulations given in Title 33 CFR, Parts 320-330 and 335-338.

Appendix A of this manual contains a reprinting of 40 CFR Parts 220-228. However, this manual addresses only the technical requirements that apply to contaminant evaluation (see §§ 227.6 and 227.13).

One of the main purposes of Section 103 of the MPRSA is to regulate and limit adverse ecological effects of ocean dumping of dredged material. Consequently, the regulations emphasize evaluative techniques such as bioassays and bioaccumulation testing, which provide relatively direct estimates of the potential for environmental impact.

1.2 APPLICABILITY

This manual is applicable to all activities involving the transportation of dredged material for the purpose of dumping it in ocean waters outside the baseline from which the territorial sea is measured. The guidance in this manual is applicable to dredging operations conducted under permits as well as to Federal projects conducted by the USACE. In this manual, terms such as *dredging project*, etc., are used in the broadest sense to include Federal projects as well as operations conducted under permits. The procedures in this manual do not apply to activities excluded by § 220.1 of the regulations.

Although it is important to remember that the regulations are legally binding and that the guidance provided in this manual is necessarily responsive to the specific requirements of these regulations, the manual is *not* intended to carry the force of law. This document does, however, contain jointly acceptable technological approaches for evaluating the potential environmental impact of the ocean disposal of dredged material as agreed upon by EPA and the USACE.

1.3 PURPOSE AND SCOPE

This manual was developed under the direction of a joint EPA/USACE work group and provides a balance between technical state-of-the-art and routinely implementable guidance for using the evaluative procedures specified in the regulations. Guidance is included on the appropriate uses and limitations of the various procedures and on sound interpretation of the results.

This manual contains summaries and discussions of the procedures for ecological evaluation of dredged material required by the regulations, tests to implement them, definitions,

sample-collection and preservation procedures, evaluative procedures, calculations, interpretive guidance, and supporting references required for the evaluation of dredged-material discharge applications in accordance with the regulations. Even so, this manual cannot stand alone. It is imperative that the supporting references be consulted for detailed or more comprehensive guidance whenever indicated. Before any evaluations are begun, THIS MANUAL *AND ESPECIALLY THE REGULATIONS IN 40 CFR 220-228* SHOULD BE READ IN THEIR ENTIRETY, and citations and references should be consulted to obtain an understanding of the guidance that the manual provides. The technical procedures in this manual are designed only for dredged material and should not be used for any other materials unless definitive research demonstrates their applicability.

This manual contains evaluative procedures considered to be acceptable tools for regulation. As warranted through experience with this manual and the development of new procedures, sections of this manual will be updated periodically and the availability of these updates will be announced. Because this manual is National in scope, it cannot address every local concern, and cannot provide detailed guidance appropriate to every such issue. Therefore, development of more detailed implementation guidance tailoring the procedures of this manual to local needs is encouraged. It is essential to the ecological evaluation approach in the manual that detailed technical agreements on the approaches to be used for all disposal applications be developed jointly and cooperatively by the EPA Regional Administrator and the USACE District Engineer, by considering the input of involved local parties and the appropriate scientists in both agencies. Local guidance has to comply with all applicable regulations, and should be compatible with the guidance in this manual. If there is disagreement between an EPA Region and a USACE District, disputes should be resolved jointly by the headquarters of EPA and the USACE.

This manual does not address management actions that could be used to reduce impact associated with dredged-material disposal. Management actions for dredged material can include control of dump releases, disposal-site capping, submarine burial, and predisposal treatment. However, these actions are both project- and region-specific and are beyond the scope of the National guidance provided by this manual. The decision as to whether such material might be allowable for ocean disposal under the MPRSA and other applicable regulations, and the procedural steps to be followed in making this determination, are issues that are beyond the scope of this manual.

1.4 ORGANIZATION OF THIS MANUAL

This manual is organized into three parts and two appendices. Part I, General Considerations, presents the purpose and background of the manual and summarizes the Federal regulations that are relevant to dredged-material evaluation. Part II, Evaluation of Potential Environmental Impact, presents guidance on the testing and evaluation of dredged material that is proposed for ocean disposal. Sections 4.0 through 7.0 of Part II describe the components of the four tiers in the tiered-testing procedure. Part III, Data Generation, presents guidance on sampling, physical and chemical analysis, biological-effects evaluation, statistical methods, and quality assurance. Appendix A is a reprint of the ocean-dumping regulations (40 CFR 220-228) and Appendix B provides technical guidance for using the numerical models to calculate initial mixing.

1.5 CHANGES FROM AND REVISIONS TO THE PREVIOUS MANUAL

This manual replaces the document *Ecological Evaluation of Proposed Discharges of Dredged Material into Ocean Waters,* published by EPA/USACE in 1977 (reprinted in 1978). This revised manual provides implementation guidance compatible with the 1977 Ocean Dumping Regulations (40 CFR 220-228) and reflects experience gained since 1977 with environmental regulation of the ocean disposal of dredged material. Although many changes have been made in the format and content of the manual, the general approach of providing the technical rationale of the regulations, test procedures, and interpretive guidance is the same, and this manual is consistent with the provisions of the existing regulations. The test endpoints and evaluative guidance have been refined, but the basic concepts are similar to those of the preceding manual.

The manual has been structured for better presentation of the expanded available information on environmental evaluation of dredged material. Part I is similar in content to Parts I and II of the 1977 manual, but with the addition of a Section that discusses the concepts of tiered testing and appropriate reference and control materials. Part II addresses how to evaluate potential environmental impact at each tier of evaluation, and provides guidance on how to use the results at each tier to make decisions. Part III is analogous to the appendices of the 1977 manual. It gives field and laboratory guidance for gathering data and discusses quality assurance/quality control considerations.

1.6 DEFINITIONS

The following terms are briefly defined and interpreted for purposes of this document. See Subpart G of the regulations for complete definitions of terms used in the regulations.

Acute toxicity

Level of mortality by a group of marine organisms that have been affected by the properties of a substance, such as a contaminated sediment. The acute toxicity of a sediment is determined by quantifying the mortality of appropriately sensitive organisms that are put into contact with the sediment, under either field or laboratory conditions, for a specified period.

Bioaccumulation

The accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated sediment or water. The regulations require that bioaccumulation be considered as part of the environmental evaluation of dredged material proposed for ocean dumping. This consideration involves predicting whether there will be a cause-and-effect relationship between an animal's presence in the area influenced by the dredged material and an environmentally important elevation of its tissue content or body burden of contaminants above that in similar animals not influenced by the disposal of the dredged material.

Constituents

Chemical substances, solids, organic matter, and organisms associated with or contained in or on dredged material.

Control sediment

A natural sediment essentially free of contaminants and compatible with the biological needs of the test organisms such that it has no discernable influence on the response being measured in the test. Test procedures are conducted witn the control sediment in the same way as the reference sediment and dredged material. The purpose of the control sediment is to confirm the biological acceptability of the test conditions and to help to verify the health of the organisms during the test. Excessive mortality in the control sediment indicates a problem with the test conditions or organisms, and can invalidate the results of the corresponding dredged material test.

Disposal site

A precise geographical area within which ocean disposal of dredged material is permitted under conditions specified in permits issued under § 103 of the MPRSA. Such sites are identified by boundaries established by (1) coordinates of latitude and longitude for each corner or by (2) coordinates of latitude and longitude for the center point and a radius in nautical miles from that point. Appropriate data for latitude and for longitude should be indicated. Boundary coordinates shall be identified as precisely as is warranted by the accuracy with which the site can be located by using existing navigational aids or through the implantation of transponders, buoys, or other means of marking the site.

Dredged material

Material excavated or dredged from waters of the United States and ocean waters.

Dumping

The disposition of material subject to the exclusions of paragraph 220.2(e) of the regulations and 33 CFR 320-330 and 335-338.

Initial mixing

That dispersion or diffusion of liquid, suspended particulate, and solid phases of dredged material that occurs within 4 h after dumping. The limiting permissible concentration (LPC) shall not be exceeded beyond the boundaries of the disposal site during initial mixing, and shall not be exceeded at any point in the marine environment after initial mixing.

Limiting permissible concentration (LPC)

The LPC for the liquid-phase concentration of dredged material in the water column is the concentration that, after allowance for initial mixing, does not exceed applicable marine water-quality criteria (WQC) or a toxicity threshold of 0.01 of the acutely toxic concentration. The LPC of the suspended particulate and solid phases is the concentration that will not cause unreasonable toxicity or bioaccumulation (see § 227.27 of the regulations for the complete definition).

Management action

Those actions that may be considered necessary to rapidly render harmless the material proposed for disposal in the marine environment (e.g., nontoxic, nonbioaccumulative).

May

May is used to mean "is allowed to"; *can* is used to mean "is able to"; and *might* is used to mean "could possibly."

Must

Must in this manual refers to requirements that have to be addressed in the context of compliance with the ocean dumping regulations.

Ocean

Those waters of the open seas lying seaward of the baseline from which the territorial sea is measured [see paragraph 220.2(c) of the regulations].

Reference sediment

A sediment, substantially free of contaminants, that is as similar as practicable to the grain size of the dredged material and the sediment at the disposal site, and that reflects the conditions that would exist in the vicinity of the disposal site had no dredged-material disposal ever taken place, but had all other influences on sediment condition taken place. These conditions have to be met to the maximum extent possible. If it is not possible to fully meet these conditions, tests should use organisms that are not sensitive to the grain-size differences among the reference sediment, control sediment, and dredged material. The reference sediment serves as a point of comparison to identify potential effects of contaminants in the dredged material.

Regulations

Procedures and concepts published in 40 CFR 220-228 for evaluating proposals for dumping dredged material in the ocean.

Should

Should is used to state that the specified condition is recommended and ought to be met unless there are clear and definite reasons for not doing so.

Whole sediment

The sediment and interstitial waters of the proposed dredged material or reference sediment before it has undergone any processing that might alter its chemical or toxicological properties. For purposes of this manual, press-sieving to remove organisms from test sediments, homogenization of test sediments, compositing of sediment samples, and additions of small amounts of seawater to facilitate homogenizing or compositing sediments may be necessary to conducting bioassay tests. These procedures are unlikely to substantially alter chemical or toxicological properties of the respective whole sediments. Alternatively, wet sieving, elutriation, or freezing and thawing of sediments may alter chemical and/or toxicological properties, and sediment so processed should not be considered as whole sediment for bioassay purposes.

1.7 REFERENCES

EPA/USACE. 1977. *Environmental Protection Agency/Corps* of Engineers Technical Committee on Criteria for Dredged and Fill Material, *Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters*. Implementation Manual for Section 103 of Public Law 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972). July 1977 (2nd printing April 1978). Environmental Effects Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

2.0 OVERVIEW OF THE REGULATIONS

The potential effects of ocean disposal of dredged material on marine organisms and human uses of the ocean may range from unmeasurable to important. These effects may differ at each disposal site, and have to be evaluated on a case-by-case basis. The regulations provide the requirements for such an evaluation, with an emphasis on the direct assessment of biological impact. The permitting procedure for proposed ocean disposal of dredged material is given in Part 225 of the regulations. Part 227 puts forth the requirements that apply to dredged-material technical evaluation and contains procedural requirements for evaluating all dredged materials proposed for ocean dumping. Section 227.1 of the regulations makes some, but not all, sections of Part 227 applicable to dredged-material evaluations. This Section of the manual summarizes the major requirements for dredged-material evaluations. However, it is essential that decisions be based on a full reading and application of the regulations, and not on this summary.

2.1 PART 225: CORPS OF ENGINEERS (USACE) DREDGED-MATERIAL PERMITS

The application and authorization for ocean disposal of dredged material are outlined in Part 225. Section 225.2 establishes the informational requirements for evaluating proposed dredged-material actions, and § 225.3 describes the procedure for evaluating the economic feasibility of alternative methods or sites. The Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) and Part 225 allow a waiver of the criteria to be sought if the proposed action is denied but dredging is essential and no feasible alternatives are available. EPA has to determine that the proposed dumping will have no unacceptable adverse effect on municipal water supplies, shellfish beds, fishery areas, wildlife areas, or recreational areas before granting the waiver.

2.2 PART 227, SUBPART A: GENERAL

Subpart A defines the applicability of Part 227, Criteria for the Evaluation of Permit Applications for Ocean Dumping of Materials, and establishes general criteria applicable to the disposal of dredged material.

2.3 PART 227, SUBPART B: ENVIRONMENTAL IMPACT

Subpart B sets general and specific criteria that have to be satisfied for disposal of dredged material in the ocean. Subpart B details procedures to be used in evaluating whether dredged material proposed for ocean dumping complies with the applicable provisions of Part 227. Section 227.5 establishes important prohibitions applicable to dredged material.

2.3.1 Trace Contaminants

Section 227.6 prohibits dumping of certain constituents as other than trace contaminants unless they are rapidly rendered harmless. This is a key section of the regulations. TRACE CONTAMINANTS ARE NOT DEFINED IN TERMS OF NUMERICAL CHEMICAL LIMITS, BUT RATHER IN TERMS OF PERSISTENCE, TOXICITY, AND BIOACCUMULATION THAT WILL NOT CAUSE AN UNACCEPTABLE ADVERSE IMPACT AFTER DUMPING. This is expressed in regulatory language in paragraphs 227.6(b) and (c).

By this definition of trace contaminants, marine organisms are regarded, in a sense, as analytical instruments for determining the environmentally adverse consequences (if any) of any contaminants present. This definition of trace contaminants requires that the lack of unacceptable adverse effect in biological studies be taken to mean that contaminants are absent, or present only in amounts and/or forms that are not environmentally active, and therefore do not exceed the trace contaminant definition. When effects occur in dredged-material tests, it is not possible within the present state of knowledge to determine which constituent(s) caused the observed effects. Therefore, it has to be assumed that they are caused by materials described in § 227.6, because it cannot be established that this is not the case. This would mean that one or more contaminants are present in greater than trace concentrations. In practice, the exact identity of the contaminant(s) causing the effect is of little concern under 40 CFR 227 because there should be no ocean disposal of dredged material that causes an unacceptable effect. Following this reasoning, unacceptable bioaccumulation of any potentially harmful constituent, whether listed in § 227.6 or not, could make the dredged material potentially undesirable.

Because assessment of trace contaminants depends upon the determination of the potential for effects, an assessment cannot be made until the impact evaluation is completed and interpreted. Only then can effects, and thus the presence of materials as other than trace contaminants, be determined.

2.3.2 Biological Evaluations

As specified in paragraph 227.13(c), the evaluation process emphasizes potential biological effects, rather than chemical presence, of the possible contaminants. Although bioassays are not precise predictors of environmental effects, they are regarded as the best methods available for integrating the effects of multiple contaminants. Bioassays for whole sediment evaluation use appropriate sensitive test organisms and record mortality as the endpoint.

Mortality of a certain percent of the organisms of a particular species in a laboratory test does not imply that the population of that species around the disposal site would decline by the same percent if the proposed disposal takes place. However, dredged-material and reference-sediment bioassay results can be compared to determine if the dredged material has significantly higher toxicity. This manual provides guidance under the regulations on determining the magnitude of mortality that may be considered to be a real increase.

Bioaccumulation is included in the required evaluations by paragraphs 227.6(b) and (c) of the regulations. Bioaccumulation indicates biological availability of contaminants in the dredged material. It also assesses the potential for long-term accumulation of contaminants in aquatic food webs to levels that might be harmful to consumers, which could include man, without killing the intermediate organisms. To use bioaccumulation in a decision, it is necessary to predict whether there will be a cause-and-effect relationship between the animal's presence in dredged material and a meaningful adverse elevation of body burden of contaminants above that of similar animals not exposed to the dredged material.

It is difficult to quantify either the ecological consequences of a given tissue concentration of a bioaccumulated contaminant or the consequences of that body burden to the animal. This manual does not provide quantitative guidance on interpreting the ecological meaning of the bioaccumulation observed. Instead, measured bioaccumulation is considered to be potentially unacceptable if animals exposed to the dredged material bioaccumulate statistically greater amounts of contaminants than do animals exposed to reference sediments. Because a statistically significant difference is not a quantitative prediction that an ecologically important impact would occur in the field, this manual presents in Sections 6.3 and 7.2 additional factors to be weighed in evaluating the potential ecological impact of bioaccumulation. This is more likely to result in environmentally sound evaluations than is reliance on statistical significance alone. However, the tests described in this manual can indicate the *potential* for such an ecological impact on a case-specific basis. As pointed out in the preceding discussion

of Part 227, Subpart B, the trace-contaminants determination cannot be made until bioaccumulation potential is evaluated.

Biological evaluations serve to integrate the chemical and biological interactions of the suite of contaminants present in a dredged-material sample by measuring their effects on test organisms. In this way, biological methods are more direct and specific than are chemical evaluations, which have to infer interactions and effects based on sediment-contaminant data alone. Within the constraints of experimental conditions and the endpoint of effect measured, biological evaluations provide a quantitative comparison of the effect of a dredged material and acceptable conditions as represented by reference sediments. Thus, a statistically significant result in this comparison indicates that the dredged material in question causes a direct and specific biological effect under test conditions and, therefore, has the potential to cause an ecologically unacceptable impact. These results will be used to determine the acceptability of the material for ocean disposal.

2.4 PART 227, SUBPART C: NEED FOR OCEAN DUMPING

Subpart C is primarily an evaluation of the need for ocean dumping. Initially, no disposal alternative is considered more desirable than any other, and the evaluation is made on a case-by-case basis. That is, confined or upland disposal cannot be considered environmentally preferable to ocean disposal unless consideration of potential environmental impact (e.g., groundwater contamination, leachate and runoff impact, permanent alteration of the site) shows it to be so. Similarly, ocean disposal cannot automatically be considered the most desirable alternative.

2.5 PART 227, SUBPART D: IMPACT OF THE PROPOSED DUMPING ON AESTHETIC, RECREATIONAL, AND ECONOMIC VALUES

Before a proposed disposal action may be approved, the probable impact on esthetics, recreation, and economic values has to be evaluated, as described in Subpart D, and information from the technical assessment described in Subpart B may be useful. Section 227.19 requires that the results of the Subpart D assessment be expressed, insofar as possible, in quantitative terms.

2.6 PART 227, SUBPART E: IMPACT OF THE PROPOSED DUMPING ON OTHER USES OF THE OCEAN

Subpart E is related to Subpart D, but it requires evaluation of specific actual or potential uses of the disposal-site environs, including but not limited to those listed in § 227.21. These are evaluations for which specific quantitative tests cannot be given. However, much information developed in the Subpart B technical evaluations will be relevant to the assessment of potential impact on living resources and their utilization.

2.7 PART 227, SUBPART G: DEFINITIONS

Subpart G provides definitions for the concepts used in test protocols for performing the evaluations required by §§ 227.6 and 227.13 of the regulations. These evaluations are required to determine compliance with the limiting permissible concentration as defined in § 227.27.

2.7.1 Limiting Permissible Concentration

2.7.1.1 Water Column

The limiting permissible concentration (LPC) applicable to potential water-column impact is defined in paragraph 227.27(a). The LPC for the portion of dredged material that will remain in the water column is the concentration of any dissolved dredged-material constituent that, after making allowance for initial mixing, will not exceed applicable marine water-quality criteria (WQC). If WQC have not been established for all of the contaminants of concern in the dredged material, or if synergistic effects are suspected, the LPC is 0.01 of the acutely toxic concentration of dredged material in the water column after the 4-h initial-mixing period [paragraph 227.29(a)]. Chemical analyses are performed for contaminants that may be released from dredged material in dissolved form, and the results are compared against the WQC for these contaminants after making allowance for initial mixing. This provides an indirect evaluation of the potential biological impact because the WQC were derived from toxicity tests of solutions of the various contaminants. In this manual, Section 4.2 discusses identification of contaminants of concern in the water column; Section 8 discusses sample-collection and preservation methods; and Section 9 discusses analytical procedures.

When dredged material contains contaminants of concern for which there are no applicable marine WQC or when synergistic effects are suspected, the material remaining in the water column has to be shown to be nontoxic and nonbioaccumulative after initial mixing. Bioassays provide information on the toxicity of contaminants not included in the WQC, and also indicate possible interactive effects of multiple contaminants. Guidance on conducting water-column bioassays is provided in Section 11 of this manual. Because concern about bioaccumulation focusses on the possibility of impact associated with gradual uptake over long exposure times, primary attention is given to dredged material deposited on the bottom. Bioaccumulation from the material remaining in the water column is generally of minor concern owing to the short exposure time and low exposure concentrations resulting from rapid dispersion and dilution. The discussion of biological evaluations in Section 2.3.2 of this manual is critical to realistically assess the potential for adverse impact on the water column.

2.7.1.2 Benthic Environment

Research conducted by EPA and the USACE since the inception of the MPRSA has shown that the greatest potential for environmental impact from dredged material is in the benthic environment. This is because deposited dredged material is not mixed and dispersed as rapidly or as greatly as the portion of the material that may remain in the water column, and bottom-dwelling animals live and feed in and on deposited material for extended periods. Therefore, the major evaluative efforts should be placed on deposited material and the benthic environment, unless there is reason to do otherwise. This manual uses a conservative approach and uses whole-sediment bioassays to evaluate potential impact of the solid phase of the dredged material. Chemical analyses of dredged material are needed to determine the presence and concentration of contaminants that might be of environmental concern, including concerns about bioaccumulation. However, at present, chemical analysis cannot be used to directly evaluate the biological effects of any contaminants, or combination of contaminants, present in dredged material because the potential effects of such contaminants depend on their bioavailability. Therefore, animals are used in bioassays to determine the biological availability of and potential for impact of contaminants associated with dredged material. Guidance on conducting bioassays with deposited dredged material is given in Section 11, and bioaccumulation guidance is given in Section 12. Understanding the discussion of biological evaluations in Section 2.3.2 is critical to the realistic assessment of the potential for impact on the benthic environment.

While sediment chemistry cannot be used to predict biological effects, it can be used to identify contaminants of concern. Chemistry can also be used to demonstrate that there is "reasonable assurance that such material has not been contaminated by such pollution [227.13(b)(3)(ii)]."

2.7.2 Estimation of Initial Mixing

Section 227.29 of the regulations describes methods for estimating initial mixing. These methods are applied in evaluating the potential for impact of the portion of dredged material that remains in the water column; all water-quality, water-column bioassa'', and bioaccumulation data have to be interpreted in light of initial mixing according to § 227.29. This is necessary since biological effects (which are the basis for water-quality criteria) are a function of the biologically available contaminant concentration and exposure time of the organisms. Laboratory bioassays expose organisms to constant concentrations for fixed periods, whereas in the field both concentration and exposure time to a particular concentration change continuously because of mixing and dilution. Both factors interact to control the degree of biological impact; thus, it is necessary to incorporate the mixing expected at the disposal site into the interpretation of data.

2.7.3 Species Selection

Paragraphs 227.27(c) and (d) specify that water-column bioassays will use appropriate sensitive water-column marine organisms, and benthic bioassays will use appropriate sensitive benthic marine organisms.

Paragraph 227.27(c) defines appropriate sensitive water-column marine organisms as at least one species each representative of phytoplankton or zooplankton, crustacean or mollusc, and fish species chosen from among the most sensitive species accepted by EPA/USACE as being reliable test organisms to determine potential water-column impact. Phytoplankton tests can theoretically indicate the potential for stimulation or inhibition by the dredged material in question. However, phytoplankton tests with the portion of dredged material remaining in the water column are extremely difficult to conduct and interpret. This is caused by interferences and predation on the test species by protozoa in the dredged material being tested. It is widely believed that potential effects on phytoplankton are generally of little environmental concern at ocean dredged-material disposal sites, because of to the extremely variable characteristics of natural phytoplankton assemblages and to the rapid mixing and dilution that occurs in the water

column. Therefore, unless there is a specific reason to be concerned about the potential effects of the proposed operation on phytoplankton, this manual recommends that a zooplankton species be selected to fulfill that portion of the species requirement. Laboratory procedures for conducting water-column bioassays are given in Section 11.

Paragraph 227.27(d) defines appropriate sensitive benthic marine organisms as at least one species each representing filter-feeding, deposit-feeding, and burrowing species chosen from among the most sensitive species accepted by EPA/USACE as being reliable organisms to determine potential benthic impact. These are broad, overlapping categories, and this manual recommends different species for bioassays and bioaccumulation testing. Whole-sediment bioassay species generally should include a deposit-feeding amphipod and a polychaete. Bioaccumulation tests generally should include a deposit-feeding bivalve mollusc and a burrowing polychaete. Procedures for conducting bioassays are given in Section 11, and bioaccumulation procedures are given in Section 12.

Part II

EVALUATION OF POTENTIAL ENVIRONMENTAL IMPACT

3.0 OVERVIEW OF TESTING AND EVALUATION

3.1 REFERENCE AND CONTROL SEDIMENTS

It is important to distinguish clearly between reference and control sediments in the context of testing for benthic impact. Test procedures are conducted on the control and reference sediments in the same way as on the dredged material proposed for ocean disposal.

3.1.1 Control Sediments

Control sediment is a natural sediment essentially free of contaminants. The essential characteristic of control sediment is that it be fully compatible with the needs of the test organisms such that it have no discernible influence on the response being measured in the test. The results of the control-sediment tests are used to verify the health of organisms used in testing and the acceptability of test conditions. Excessive mortality in the control sediment indicates a problem with testing conditions or organisms and can invalidate the corresponding test results.

3.1.2 Reference Sediment

Reference sediment is the key to evaluating the benthic effects of dredged material. Results of tests using reference sediment provide the point of comparison (reference point) against which effects of dredged material are compared. A determination of the potential for dredged material proposed for disposal to cause unacceptable adverse impact can be made by comparing results of tests using reference material to the results of tests using dredged material.

A reference sediment is a sediment, substantially free of contaminants, that is as similar to the grain size of the dredged material and the sediment at the disposal site as practical, and reflects conditions that would exist in the vicinity of the disposal site had no dredged-material disposal ever occurred, but had all other influences on sediment condition taken place. For optimal evaluation of the toxicity and bioaccumulation potential of a dredged material, these *reference-sediment conditions* have to be met to the maximum extent possible. If it is not possible to fully meet these conditions, tests should use organisms that are not sensitive to grain-size differences among the reference sediment, control sediment, and dredged material. The reference sediment serves as a point of comparison to identify potential effects of

contaminants in the dredged material. It may be appropriate to test more than one reference sediment to evaluate a single dredging project.

3.1.2.1 Reference-Sediment Sampling Location

According to the definition in Section 1.6, reference sediment is substantially free of contaminants, as similar as practical to the grain size of the dredged material and the sediment at the disposal site, and reflects conditions that would exist in the vicinity of the disposal site had no dredged-material disposal ever taken place, but had all other influences on sediment condition occurred. With this in mind, reference sediment is collected outside the boundaries of the dredged-material disposal site, but near enough to the disposal site that the reference sediment is in the same water mass and subject to all the same influences (except previously disposed dredged material) as the disposal site. If there is a potential for sediment migration, reference sediment should not be collected from the area outside the disposal site in the direction of net sediment transport.

Reference sediment may be collected from a single reference-sediment sampling point that satisfies the conditions in this section and meets the requirements of the reference-sediment definition in Section 1.6. This is known as the reference-point approach.

Alternatively, reference sediment may be collected from a number of locations within a reference area that satisfies the conditions in this section and meets the requirements of the reference-sediment definition in Section 1.6. This is known as the reference-area approach.

In the reference-area approach, the reference location is viewed not as a single station or point but as the entire area in the environs of the disposal site, excluding the disposal site itself. Rather than characterize the reference area by sampling at a single point, it is characterized by a number of samples taken throughout the reference area. The intensity of the reference-sediment sample gathering should be tailored to the physical, chemical, and biological characteristics of the disposal site, particularly the dispersal characteristics of the site. Reference-area samples may be composited according to the compositing guidance in Section 8.2.4. The composited or individual samples are then tested for chemistry, toxicity, and bioaccumulation by the same methods used for dredged-material testing. The reference data thus generated are compared to the corresponding dredged-material data in the same way that reference data have traditionally been used.

3.1.2.2 Reference-Sediment Sampling Interval

Reference sediment has to be collected and tested at the time of each dredged-material test if the reference-point approach is used. In this approach, a new sample of reference sediment is collected from the specified reference-sediment sampling point for each test or test series and is tested simultaneously with the dredged material being evaluated.

Logistical considerations might make it impractical to use the reference-area approach at the time of each test. Reference-area sampling may be conducted periodically as part of a monitoring/management plan for a disposal site. Reference sediment is collected from the reference area, and all appropriate chemistry, bioassay, and bioaccumulation tests are performed on it. The reference data thus generated are used as the basis for evaluating all dredged material tested during some specified period. The reference area is resampled and retested to update the reference data as appropriate.

Using the periodic reference-area approach, reference data are established for each disposal site and for each type of test. To conduct the evaluations put forth in this manual, reference-area data for the proposed dredged material for the specified disposal period must be established for

- Test-species benthic toxicity
- Test-species benthic bioaccumulation period
- Each contaminant that is likely to be of concern at that site.

Development of reference data using all appropriate species and contaminants for all dredged material that may be proposed for a disposal site during the specified period will require planning and coordination. However, most ocean-disposal sites receive dredged material from relatively few locations so that standardization of species for testing and advance identification of potential contaminants of concern for bioaccumulation should be possible.

3.1.2.3 Reference-Sediment Sampling

The importance of thoughtful selection of the approach to reference-sediment sampling cannot be overemphasized. To ensure that the reference sediment is properly located, information gathered during the site-designation process or other similar studies should be completed for both the disposal site and the reference area. Information on the potential for migration of dredged material from the disposal site is particularly important in this regard.

A well-designed sampling plan is essential to the collection, preservation, and storage of samples so that potential toxicity and bioaccumulation can be accurately assessed (see Section 8). The implementation of such a plan is equally essential for dredged material, control sediment, and reference-sediment sampling. The sample collection, preservation, and storage guidance of Section 8 is applicable to dredged material, control sediment, and reference sediment.

3.2 TIERED TESTING AND EVALUATION

The tiered approach to testing used in this manual is designed to aid in generating necessary toxicity and bioaccumulation information, but not more information than is necessary. This allows optimal use of resources by focusing the least effort on dredging operations where the potential (or lack thereof) for unacceptable adverse impact is clear, and expending the most effort on operations requiring more extensive investigation to determine the potential (or lack thereof) for impact. To achieve this objective, the procedures in this manual are arranged in a series of tiers, or levels of intensity of investigation. The initial tier uses readily available information that may be sufficient for evaluation in some cases. Dredging operations that obviously have low environmental impact generally should not require intensive investigation to reach a decision. Evaluation at successive tiers is based on more extensive and specific information that may be more time-consuming and expensive to generate, but that allows more and more comprehensive evaluations of the potential for environmental effects.

A tiered, or hierarchical, approach to testing and evaluation allows the use of a necessary and sufficient level of testing for each specific dredging operation. The initial tiers (Tiers I and II) use existing information and relatively simple, rapid procedures for determining potential environmental impact of the dredged material in question. For certain dredged materials with readily apparent potential for environmental impact (or lack thereof), information collected in the initial tiers may be sufficient for making decisions. However, more extensive evaluation (Tiers III and IV) may be needed for other materials with less clear potential for impact or for which the information is inadequate. Successive tiers incorporate more intensive evaluation procedures that provide more detailed information about potential impact of the dredged material. The intent of the tiered approach is to use resources efficiently by testing only as intensely as is necessary to provide sufficient information for making decisions. The tiered approach minimizes excessive testing of dredging operations for which this is unnecessary and appropriately directs more intense testing to operations that require more technical information

for evaluation. Tiered testing results in more efficient completion of required evaluations and reduced costs, especially to low-risk operations.

It is neither necessary nor desirable that all dredged material be evaluated through all tiers in sequence. If information warrants, it is acceptable to proceed directly to Tier II, III, or IV. It is also fully acceptable to carry water-column and benthic evaluations, or toxicity and bioaccumulation evaluations, to different tiers to generate the information necessary and sufficient to determine compliance with the regulations.

Prior to initiating testing, it is essential that the informational requirements of preceding tiers be thoroughly understood and that the information necessary for decision-making at the advanced tier be assembled. For example, it is always appropriate to gather all relevant available information and identify the chemicals of concern for the dredged material in question. Although these activities are components of Tier I, they have to be conducted even if a complete evaluation at the initial tiers is not considered appropriate. Similarly, water-column evaluations require that Tier II be completed to obtain information sufficient for an LPC determination in Tier II, III, or IV.

It is necessary to proceed through the tiers only until information sufficient to determine compliance or noncompliance with §§ 227.6 and 226.13 has been obtained. For example, if the available information is sufficient to demonstrate that the LPC is met, no further testing is required. Similarly, if historical data have consistently shown a particular dredged material to exceed the LPC, an exhaustive evaluation may not be warranted. After any of the first three tiers is completed, one of three decisions can be made according to the evaluative guidance in Sections 4 through 7 of this manual: (1) information is sufficient to determine that the LPC is met, (2) information is sufficient to determine that the LPC is not met, or (3) information is insufficient to make a determination. In the last case, if ocean disposal is still to be considered, the evaluation would proceed to a higher tier for further testing. In unusual circumstances, where a compliance determination cannot be made after completion of the first three tiers, further testing in Tier IV may be appropriate. Tier IV tests have to be carefully designed to supply all information necessary to make a determination on whether the dredged material meets the LPC.

If the information is insufficient to determine LPC compliance after completing Tier I, II, or III, further testing is not required if noncompliance with the LPC is assumed.

The Tier I evaluation helps to identify the needed information and to determine appropriate tiers and tests necessary to collect this information. In all cases, it is appropriate to gather the information used in Tier I, although it may be clear without formal Tier I evaluation that

further assessment will be necessary. It is, however, always necessary to identify the contaminants of concern, if any, at the Tier I level. Tiers I, II, and III are intended to suffice for almost all evaluations. Tier IV is intended only for extremely rare occasions.

With some dredged materials, biological effects will be easily determined, but bioaccumulation potential will require more investigation, or vice versa. In other cases, determining potential benthic effects may require more investigation than evaluating water-column effects. The tiered-testing approach used in the manual accommodates such situations by providing independent evaluation of biological effects and bioaccumulation and of water-column and benthic effects only to the extent needed to make a decision about each.

The tests in the tiers presented in the manual reflect the present state-of-the-art evaluation procedures for dredged-material evaluation. The procedures will be improved and updated as scientific knowledge increases. Part III of this manual provides the testing guidance for each tier, and includes specific guidance on topics such as test selection, test design and conditions, determining acceptability of tests, and statistical frameworks for interpretation of results. Here, in Part II, evaluative guidance is provided for using bioassay and bioaccumulation data from each tier of testing to determine compliance with the regulations.

It is important to emphasize that testing at every tier is not required for every situation. However, evaluations conducted in Tiers II, III, and IV may utilize information that was collected in preceding tiers. Thus, skipping tiers may not produce any time or resource savings. At any tier, failure to satisfactorily determine the potential for unacceptable environmental impact results in additional testing at a subsequent, more complex tier unless a decision is made to seek other disposal alternatives. If there is reason to believe that there is contamination and that the available information is not adequate to support a decision, testing can begin at Tier II, III, or IV without conducting the evaluation at each preceding tier.* It would be extremely unusual to go directly to Tier IV. The tiered-testing approach permits the flexibility to evaluate dredged materials in the most efficient way. More complex evaluation techniques are necessary only in those situations where the potential effects of contaminants in the dredged materials can be evaluated only with additional technical information.

Although the tiered-testing approach outlined in this manual provides an effective means of implementing the regulations, it is recognized that the evaluation of dredged material is an evolving field. It is anticipated that, as new methods of evaluation are developed and accepted, they can be integrated into the tiered framework. With the advent of acceptable new evaluation

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*Note that Tier II water-column evaluation is required if water-column LPC compliance cannot be shown in Tier I.

procedures, the tiered approach will be maintained because of the efficiency afforded by its hierarchical design.

The tiered approach used in the manual is summarized in Figure 3-1, and additional detail on water-column and benthic evaluation is presented in Figures 3-2 and 3-3. These flowcharts should be used in conjunction with a careful reading of the corresponding guidance presented in the text. The Sections in the manual that present the technical and decision-making guidance shown by the flowcharts are indicated in the boxes on the Figures.

The following discussion briefly overviews the testing and evaluation guidance in the manual, and integrates the Figures with the text. By necessity, this overview is not detailed, and cannot be used on a standalone basis for regulation.

As illustrated in Figure 3-1, the evaluation begins in Tier I with the compilation of all available information relevant to the operation in question (Section 4.1). If the chemical information is not adequate, a chemical analysis of the dredged material should be performed on contaminants of concern. Information collected in Tier I is evaluated to determine whether it is sufficient for decision-making, as described in Section 4.3. If the information is sufficient, a determination is made (Figure 3-1) as to whether the material is (1) sand, (2) suitable for beach nourishment, or (3) similar to the disposal site and from an area far removed from pollution sources (Section 4.3). If so, the material meets the paragraph 227.13(b) criteria, meets the LPC, and is acceptable for ocean disposal at a designated site if all other requirements of the regulations are satisfied. If not, the existing information (which has already been judged sufficient for decision-making) is used to determine whether the dredged material can be disposed without exceeding the LPC in compliance with paragraph 227.13(c) of the regulations (Figure 3-1 and Section 4.3). This is the same standard used to judge acceptability in Tiers II-IV when new data are necessary.

If, in Tier 1, the dredged material is found to meet the LPC and paragraph 227.13(c), no further information on contaminants is required to determine compliance. Alternatively, the dredged material may be found to not meet the LPC and paragraph 227.13(c). In either case, the decisions on whether such material might be allowable for ocean disposal under the MPRSA and other applicable regulations, and the procedural steps to make this determination, are issues beyond the scope of this manual. If the initial information is insufficient for determining compliance, further evaluation in Tiers II, III, and/or IV, as necessary, is required (Figures 3-2 and 3-3).

If water-column impact cannot be fully evaluated in Tier I, completion of Tier II is mandatory to determine compliance with applicable marine water-quality criteria (WQC)

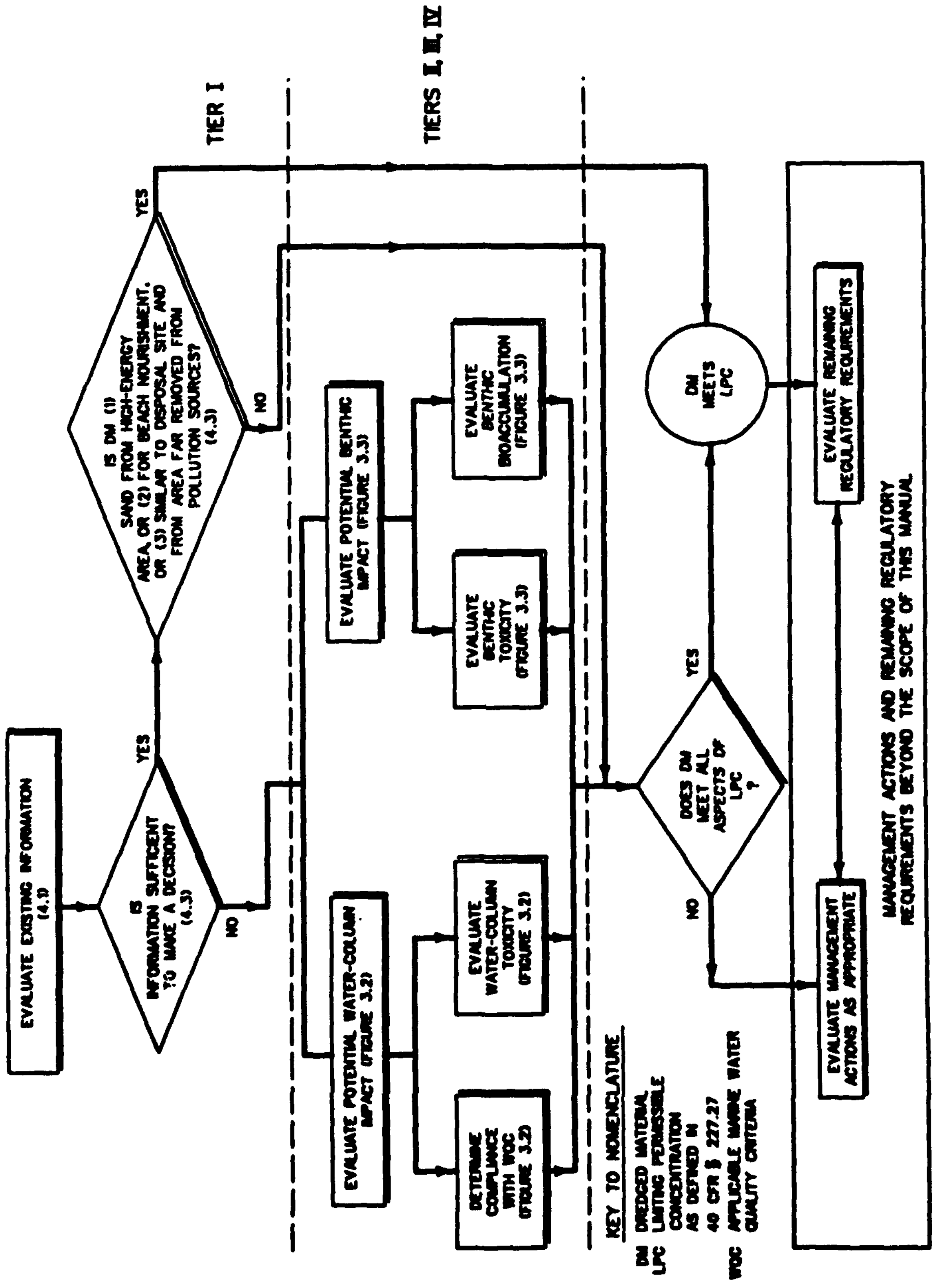

Figure 3-1. Overview of Tiered Approach to Evaluating Potential Impact of Ocean Disposal of Dredged Material. Sections in which applicable discussions begin in the manual are indicated by the numbers within the parentheses.

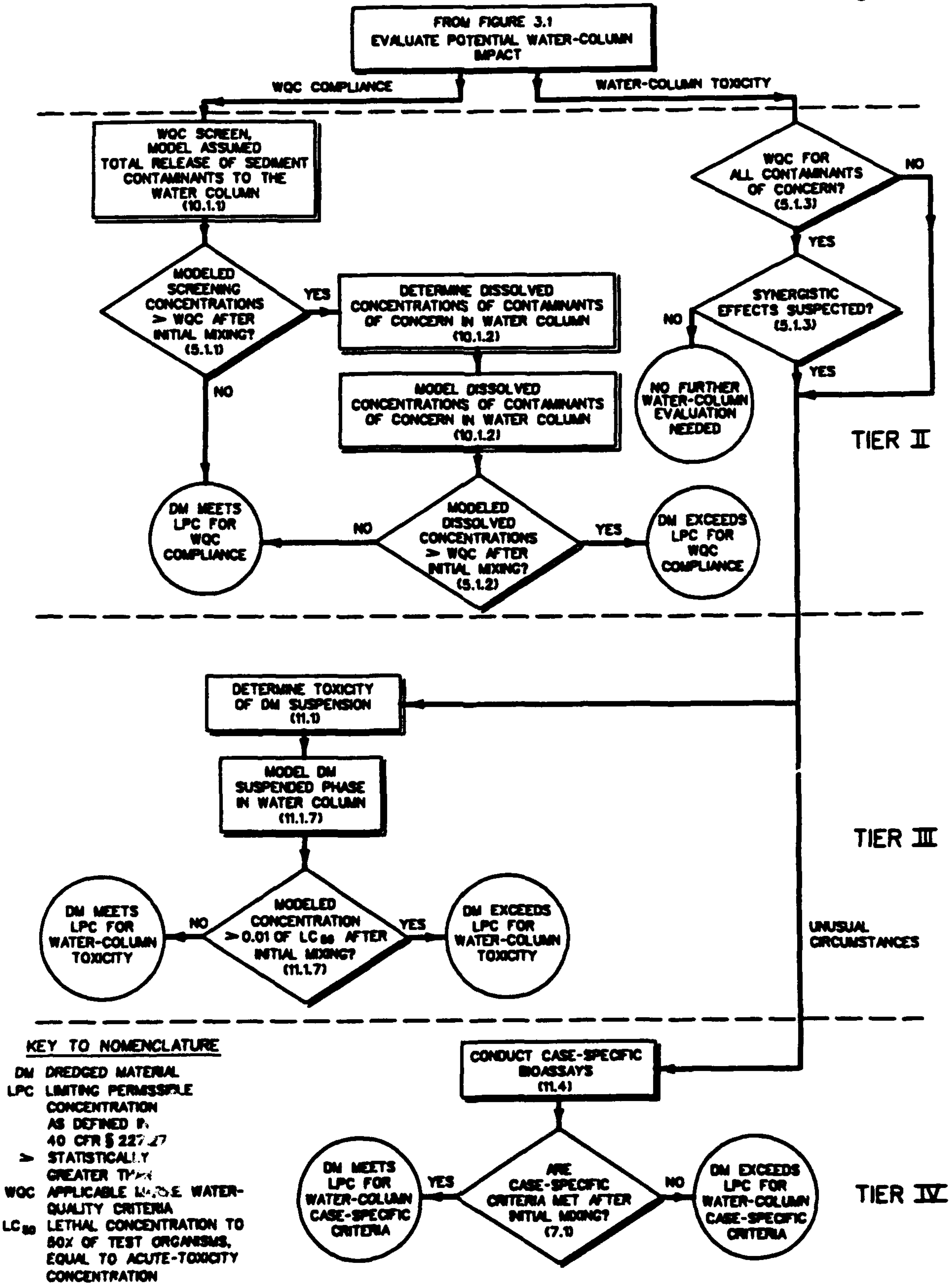

Figure 3-2. Tiered Approach to Evaluating Potential WATER-COLUMN IMPACT of Dredged Material. Sections in which applicable discussions in the manual are indicated by the numbers within the parentheses.

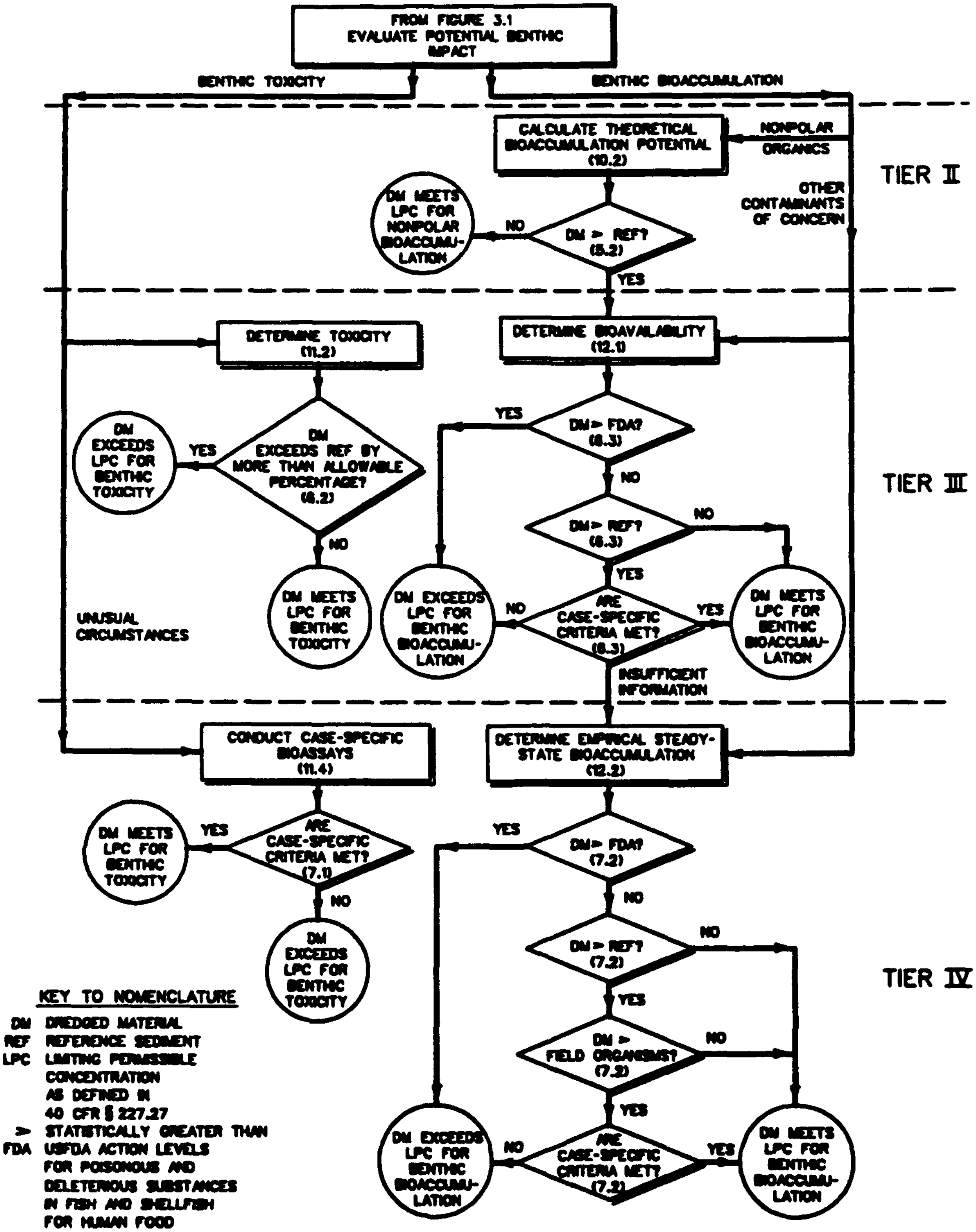

Figure 3-3. Tiered Approach to Evaluating Potential BENTHIC IMPACT of Deposited Dredged Material. Sections in which applicable discussions begin in the manual are indicated by the numbers within the parentheses.

(Figure 3-2). This evaluation is conducted by entering the known contaminant concentrations into a numerical mixing model as described in Section 10.1.1. The sediment-concentration data entered in the model at this point are those which were identified in the Tier I evaluation. Total release of the contaminants into the water column is assumed, thereby using the model as a screen and being able to show LPC compliance for dredged material that will cause very little impact on the water column. However, if the model screen predicts that the WQC will be exceeded, an elutriate test must be conducted and the results from the sediment chemical analysis and evaluation used to determine the concentration of contaminants that might enter the water column during a disposal operation (Section 10.1.2). Following the sediment chemical analysis, the model is run a second time, using the elutriate chemical data that more closely represent the available contaminants. If the model predicts again that the WQC will be exceeded, the LPC for WQC compliance is not met. Conversely, if the model shows that the WQC are not exceeded, the LPC is met for WQC compliance. However, when there are no WQC for all contaminants of concern, or synergistic effects are suspected among the contaminants, water-column impact must also be evaluated by toxicity testing [paragraph 227.13(c)(2)(ii)] in Tier III.

In Tier II, the potential for benthic impact related to bioaccumulation of nonpolar organic compounds is evaluated according to the guidance in Section 10.1 (Figure 3-3). This involves calculation of theoretical bioaccumulation potential (TBP) of nonpolar organic compounds based on partitioning between the organic carbon in sediments and the lipids in organisms (see Section 10.2). If the T 3P is lower from the dredged material than from the reference sediment, further testing for bioaccumulation of these nonpolar organic contaminants is not required. If the TBP of the dredged material exceeds that of the reference sediment, or if there are contaminants of concern that are not nonpolar organics, bioaccumulation testing in Tiers III and/or IV is required (Section 5.2 and Figure 3-3).

It should be recognized that Tier II consists only of a numerical model to determine compliance with the WQC and a calculation to estimate the TBP for nonpolar organic compounds. As presently structured, Tier II cannot be used to fully determine LPC compliance for dredged material. Research is being conducted to develop new water-column and benthic tests for this tier which will allow more definitive LPC evaluations.

Tier III water-column testing consists of evaluation of the toxicity of the suspended and dissolved portions of the dredged material that remain in the water column, after consideration of initial mixing (see Section 11.1 and Figure 3-2). If the model predicts that the dredged-material

concentration remaining in the water column after initial mixing is greater than 0.01 of the corresponding LC_{50}, the LPC for water-column impact is not met (see Section 6.1 and Figure 3-2). If the predicted concentration is less than 0.01 of the LC_{50}, the LPC for water-column impact is met and compliance is further assessed for benthic impact and other regulations (see Section 6.1 and Figure 3-2).

Tier III benthic tests consist of acute toxicity bioassays (Section 11.2) and bioaccumulation tests (Section 12.2), as illustrated in Figure 3-3. When sublethal chronic tests are approved for dredged-material evaluation, they will be incorporated into this Tier. At present, benthic impact is evaluated by comparing dredged-material toxicity against the reference sediment (Figure 3-3). The LPC is not met for benthic toxicity (Section 6.2, and Figure 3-3) if the dredged-material toxicity (1) is statistically greater than the reference sediment and (2) exceeds reference-sediment toxicity by at least 10%-20% (see Section 6.2 for the applicable percentage). This approach is discussed in more detail in Section 6.2. The LPC for benthic toxicity is met if the toxicity of the dredged material does not statistically exceed that of the reference material by more than the applicable percentage (Section 6.2 and Figure 3-3).

Bioaccumulation of dredged-material contaminants of concern is assessed in Tier III by comparing the bioavailability of the contaminants against the Food and Drug Administration Action Levels for Poisonous and Deleterious.Substances in Fish and Shellfish for Human Food and to the bioavailability of contaminants in the reference sediment. If any of the FDA levels is statistically exceeded (Section 6.3 and Figure 3-3), the LPC is not met for bioaccumulation. If results show that the FDA levels are not exceeded but that the reference-sediment values are exceeded, further evaluation using case-specific criteria is required (Section 6.3 and Figure 3-3). The case-specific criteria are to reflect the local information that addresses the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) of the regulations. If results show that neither the FDA levels nor reference-sediment values are exceeded, the dredged material meets the LPC for bioaccumulation. The purpose of this case-specific evaluation in Tier III is to reach an environmentally sound LPC evaluation for bioaccumulation without having to commit additional time and resources under Tier IV testing, unless necessary.

Tier IV bioassay testing is intended only for infrequent application, under unusual circumstances that warrant specifically designed case studies (Figure 3-1). Tier IV water-column and benthic bioassays are discussed in Section 11, and interpretive guidance is discussed in Sections 7.1 and 7.2. Tier IV benthic and water-column bioassays have to be interpreted in relation to case-specific criteria (Figures 3-2 and 3-3) developed as discussed in Section 7.1. Tier IV bioaccumulation evaluation consists of determination of steady-state bioaccumulation of

dredged-material contaminants (Figure 3-3), as described in Section 12.2. If a steady-state body burden statistically exceeds an FDA level for a single contaminant, the LPC for bioaccumulation is not met (Section 7.2 and Figure 3-3). If the body burdens of animals exposed to the dredged material do not exceed any FDA levels or the body burdens of the reference animals, the LPC is met (Section 7.2 and Figure 3-3). Animal body burdens not statistically exceeding FDA levels but statistically higher than those of the reference-sediment animals are compared to the body burdens in similar organisms living around, but not in, the proposed disposal site. If the body burdens from the dredged-material animals do not statistically exceed the body burdens of these field organisms, the LPC is met (Section 7.2 and Figure 3-3). If body burdens from the dredged-material animals exceed those of field organisms, case-specific criteria for the dredging operation must be developed (Section 7.2 and Figure 3-3). Evaluation of body burdens using the case-specific criteria in Tier IV provides for a yes/no compliance evaluation with the LPC for bioaccumulation.

If the above procedures show that the LPC cannot be met, management-action alternatives will have to be considered if the ocean-disposal option is to be pursued. Management actions are project-specific and are addressed in other EPA/USACE documents. The decisions as to whether such material might be allowable for ocean disposal under the MPRSA and other applicable regulations, and the procedural steps to be followed in making this determination, are issues that are beyond the scope of this manual.

In summary, the tiered, or hierarchical, testing approach presented in this manual allows the appropriate level of testing to be used for each specific dredging operation.

4.0 TIER I

The purpose of Tier I is to determine whether a decision on compliance with the limiting permissible concentration (LPC) can be made on the basis of existing information. Tier I is a comprehensive analysis of *all* existing and readily available, assembled, and interpreted information on the proposed dredging project, including all previously collected physical, chemical, and biological data. Part III of this manual, particularly Sections 9, 10, 11, and 12, is to be consulted when evaluating the information obtained during Tier I evaluations.

If the information set compiled in Tier I is complete and comparable to that which would appropriately satisfy Tier II, III, or IV, a decision on LPC compliance can be completed without proceeding into the higher tiers (Figure 3-1). For an LPC evaluation to be completed within Tier I, the weight of evidence of the collected information must convincingly show that the dredged-material disposal will or will not meet the LPC.

For a Tier I evaluation, the information collected on the proposed dredged material is first compared to the three exclusionary criteria in paragraph 227.13(b). If one or more of the exclusionary criteria can be satisfied, the LPC is met for the dredged material and no further evaluation is required. If no exclusionary criteria can be met, the LPC is evaluated based on the collected information. This information must include data analyses of the toxicity and bioaccumulation potential of the dredged material and of the reference sediments. The information must also be sufficient to determine if the WQC or 1% of the LC_{50} will be exceeded in the water-column following the initial-mixing period. If there is not adequate information available for a Tier I LPC evaluation, the evaluation process moves to Tier II.

It is important to note that, even if a final LPC evaluation is not reached within Tier I, the information collected can be put to use in later tier analyses. A primary purpose of Tier I is to identify the contaminants of concern (if any) in that particular dredged material. This information is used to select analyses in Tiers II, III, and IV. Similarly, other information collected in Tier I may be used to satisfy all or portions of evaluations in other tiers. It is necessary to proceed through the tier-testing mechanism only until a definitive LPC evaluation is reached for potential water-column impact and for the toxicity and bioaccumulation components of benthic impact. Rigorous information collection and assessment in Tier I inevitably saves time and resources in making final LPC determinations.

Annual or episodic dredging, undertaken to maintain existing navigation improvements, may warrant a Tier I reevaluation prior to each episode. The recommendation of EPA and the USACE is that the interval between reevaluation of Tier I data for these projects not exceed 3 years. This reevaluation minimally should include reassessment of all new and previously evaluated physical and chemical data relative to any regulatory changes, changes in sediment composition or deposition (e.g., industrial development in the watershed), improvements in analytical methods and contaminant detectability, and quality-assurance considerations.

4.1 COMPILATION OF EXISTING INFORMATION

The focus of the Tier I evaluation is on paragraph 227.13(b) and the potential for contaminant-associated impact upon ocean dumping. The information-gathering phase of Tier I evaluations has to be as complete as is reasonably possible, and existing information from all reasonably available sources has to be included. Although there are no minimum requirements, a more complete inventory of available information will increase the likelihood that decisions concerning the impact of dredged material may be made at initial tiers. Sources of available information include the following, without limitation.

- Available results of prior physical, chemical, and biological tests of the material proposed to be dumped.
- Available results of prior field monitoring studies of the material proposed to be dumped (e.g., physical characteristics, organic-carbon content, and grain size).
- Available information describing the source of the material to be dumped which would be relevant to the identification of potential contaminants of concern.
- Existing data contained in files of either the EPA or USACE or are otherwise available from public or private sources. Examples of sources from which relevant information might be obtained include
    - Selected Chemical Spill Listing (EPA)
    - Pesticide Spill Reporting System (EPA)
    - Pollution Incident Reporting System (United States Coast Guard)
    - Identification of In-Place Pollutants and Priorities for Removal (EPA)
    - Hazardous waste sites and management facilities reports (EPA)
    - USACE studies of sediment pollution and sediments
    - Federal STORET, BIOS, CETIS, and ODES databases (EPA)
    - Water and sediment data on major tributaries (Geological Survey)
    - NPDES permit records
    - CWA 404(b)(1) evaluations
    - Pertinent and applicable research reports
    - MPRSA 103 evaluations
    - Port Authorities
    - Colleges/Universities

- Records of State environmental agencies
- Published scientific literature

Evaluation of all reasonably available information allows determination of the potential for contaminants to have been introduced to the dredged material. This information, evaluated with consideration of the physical nature of the dredging site, dredged material, and the proposed disposal site, allows a determination of whether the dredged material complies with paragraph 227.13(b) (Appendix A). Decisions about compliance will be made on a case-by-case basis for each proposed disposal operation, and specific quantitative guidance applicable to all situations nationwide cannot be offered. More detailed guidance for reaching decisions about compliance may be developed by the EPA Region and USACE District by considering available scientific information and locally important concerns. This information will be important in reaching an administrative decision that complies with the requirements of paragraph 227.13(b). In evaluating the likelihood that disposal of a dredged material may cause contaminant-associated impact, concern *decreases* with the increase of factors such as

- Isolation of the dredging operation from known existing and historical sources of pollution
- Time since historical sources of pollution have been remediated
- Number and frequency of maintenance dredging operations since abatement of the source of contamination
- Mixing and dilution occurring between the contamination source and the dredging site
- Transport and potential deposition of sediment in the dredging area from sources other than those potentially affected by contamination
- Grain size of the dredged material.

Concern regarding contaminant-associated impact *increases* with the increase of factors such as the number, amount, and toxicological importance of contaminants

- Known to have been introduced to the dredging site
- Suspected to have been introduced to the dredging site
- With continuing input from existing sources
- From historical sources no longer active.

These and other considerations are complexly interrelated; i.e., the acceptable degree of isolation from sources of pollution depends on the number, amount, and toxicological importance of the contaminants as well as on all other factors. These considerations have to be evaluated for all dredged material. Even so, it is desirable that local guidance be developed, based on technical evaluations, that describes the emphasis on factors deemed appropriate in

each area. In all cases, the decisions that are based on these factors have to comply with the requirements of paragraph 227.13(b).

4.2 IDENTIFICATION OF CONTAMINANTS OF CONCERN

In the Tier I decision sequence (Figure 3-1), the first possibility is that more information is required to determine compliance with the regulations. A critical prerequisite to generating this information is deciding, on a case-by-case basis, which contaminants are of concern in the particular dredged material being evaluated. To determine the contaminants of concern, it may be necessary to supplement available information with additional chemical analyses of the dredged material.

On a National scale, dredged material may contain a variety of chemicals. It is difficult to specify a single set of contaminants that adequately addresses all environmental concerns about all dredged materials in the country. The contaminants of concern in a particular dredged material have to be identified on a case-by-case basis. In some dredged materials, there may be no contaminants of concern. Different dredging operations may have their own set of contaminants of environmental concern that should be adequately evaluated for each operation. The selection of the appropriate contaminants of concern for each dredged material is crucial to the success of the testing program.

Identifying specific contaminants, if any, that are of concern in a particular dredged material is dependent on the information collected for Tier I, which provides a preliminary basis for determining potential contamination of the dredged material. In some instances, it may be sufficient to perform confirmatory analyses for specific contaminants of concern. In other cases, where the initial evaluation indicates that a variety of contaminants of concern may be present, chemical analysis of the dredged material could provide a useful inventory, and a bulk-chemical analysis conducted according to the guidance in Section 9.3 may be appropriate and, in fact, would be necessary to conduct Tier II.

From the list of contaminants shown to be potentially present in a dredged material, it is necessary to determine which specific contaminants are of concern in terms of potential environmental impact. Some contaminants are always of interest because of the provisions of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention; LDC) and the incorporation of these contaminants into the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) and §§ 227.5 and 227.6 of the regulations. In identifying contaminants of concern, the contaminants necessary to determine

compliance with the requirements of § 227.6 of the regulations have to be included. Other contaminants that should be included are those that might reasonably be expected to cause unacceptable adverse impact if the dredged material in question were placed in the ocean.

Current knowledge is inadequate to predict biological effects based on the presence of contaminants in dredged material. Therefore, those chemicals identified as contaminants of concern are evaluated according to the biological effects-based criteria in § 227.13 (Appendix A). Sediment-chemistry data describing the concentration of contaminants of concern should not be directly used to make decisions regarding the acceptability of dredged material for ocean disposal. This information should be considered when selecting appropriate bioassay/ bioaccumulation testing procedures and species to be evaluated, and when reviewing the results obtained from these tests. That is, the presence and levels of contaminants of concern can be used on a case-by-case basis when reviewing the validity of bioassay/bioaccumulation results. Chemistry data should be used only as a feedback trigger to indicate the need for further evaluation of quality assurance/quality control (QA/QC) to assist in determining if the bioassay/ bioaccumulation tests to determine if the tests were properly conducted. If the QA/QC review indicates that the tests were improperly conducted, retesting would be appropriate.

The contaminants of concern in each dredged material should be identified on the basis of the following, keeping in mind the discussion in Sections 9.3 and 9.4 and the requirements of § 227.6 of the regulations:

- Presence in the dredged material
- Presence in the dredged material relative to the concentration in the reference material
- Toxicological importance
- Persistence in the environment
- Propensity to bioaccumulate from sediments
  The major chemical properties controlling the propensity to bioaccumulate are

  Hydrophobicity
  Literally, "fear of water"; the property of neutral (i.e., uncharged) organic molecules that causes them to associate with surfaces or organic solvents rather than to be in aqueous solution. The presence of a neutral surface such as an uncharged organic molecule causes water molecules to become structured around the intruding entity. This structuring is energetically unfavorable, and the neutral organic molecule tends to be partitioned to a less energetic phase if one is available. In an operational sense, hydrophobicity is the reverse of aqueous solubility. The octanol/water partition coefficient (K_{ow}, log K_{ow}, or log P) is a measure of hydrophobicity. The tendency for organic chemicals to bioaccumulate is related to their hydrophobicity. Bioaccumulation factors increase with increasing hydrophobicity up to a log K_{ow} of about 6.00. At

hydrophobicities greater than about log K_{ow} = 6.00, bioaccumulation factors tend to not increase due, most likely, to reduced bioavailability.

Aqueous Solubility
Chemicals such as acids, bases, and salts that speciate (dissociate) as charged entities tend to be water-soluble and those that do not speciate (neutral and nonpolar organic compounds) tend to be insoluble, or nearly so. Solubility favors rapid uptake of chemicals by organisms, but at the same time favors rapid elimination, with the result that soluble chemicals generally do not bioaccumulate to a great extent. The soluble free ions of certain heavy metals are exceptional in that they bind with tissues and thus are actively bioaccumulated by organisms.

Stability
For chemicals to bioaccumulate, they must be stable, conservative, and resistant to degradation. Organic compounds with structures that protect them from the catalytic action of enzymes or from nonenzymatic hydrolysis tend to bioaccumulate. Phosphate ester pesticides do not bioaccumulate because they are easily hydrolyzed. Unsubstituted polynuclear aromatic hydrocarbons (PAH) can be broken down by an initial enzymatic opening of ring structures. The presence of electron-withdrawing substituents tends to stabilize an organic molecule. Chlorines, for example, are bulky, highly electronegative atoms that tend to protect the nucleus of an organic molecule against chemical attack. Chlorinated organic compounds bioaccumulate to high levels because they are easily taken up by organisms, and, once in the body, they cannot be readily broken down and eliminated.

Stereochemistry
The spatial configuration, i.e., stereochemistry, of a neutral molecule affects its tendency to bioaccumulate. Molecules that are planar tend to be more lipid-soluble (lipophilic) than do globular molecules of similar molecular weight. For neutral organic molecules, planarity generally correlates with higher bioaccumulation unless the molecule is easily metabolized by an organism.

These and other considerations important to identifying contaminants of concern are complexly interrelated and have to be evaluated individually for each dredged material. Even so, it is desirable that local guidance be developed, based on technical evaluations, that describes the emphasis on various factors deemed appropriate for identifying contaminants of concern in each area. In all cases, the decisions based on these factors have to comply with the requirements of § 227.13 (Appendix A).

4.3 DETERMINATION OF COMPLIANCE

After consideration of all available information, one of the following conclusions is reached (Figure 3-1).

- Existing information does not provide a sufficient basis for making a decision about whether dredged material complies with § 227.13 of the regulations. In this case, further evaluation in Tiers II, III, and/or IV is appropriate.
- Existing information provides a sufficient basis for making a decision about whether the dredged material complies with § 227.13 of the regulations.

In the latter case, based on consideration of available information, one of the following conclusions is reached (Figure 3-1).

- The material complies with the paragraph 227.13(b) criteria for exclusion from further testing (Appendix A). If so, no further information on contaminants is necessary to determine compliance.
- The material does not comply with the paragraph 227.13(b) criteria, but does comply with the paragraph 227.13(c) criteria and the limiting permissible concentration (Appendix A). If so, no further information on contaminants is necessary to determine compliance.
- The material does not comply with either the paragraph 227.13(b) or the paragraph 227.13(c) criteria and with the LPC (Appendix A). If so, no further information is necessary to determine noncompliance.

5.0 TIER II EVALUATION

Tier II consists of evaluation of marine water-quality criteria (WQC) compliance using a numerical mixing model of the dump-site conditions (Figure 3-2 and Appendix B) and an evaluation of the potential for benthic impact using calculations of theoretical bioaccumulation potential (Figure 3-3 and Section 10.2). The purpose of Tier II is to provide a reliable, rapid screen for potential impact and thereby eliminate the need for further testing. The dredged-material impact in the water column must be within the applicable marine WQC for all contaminants of concern outside the boundary of the site at all times and within the site following the 4-h initial-mixing period (Figure 3-2). When there are no WQC for all contaminants of concern, or when synergistic effects are suspected between the contaminants, water-column impact must also be investigated by toxicity testing [paragraph 227.13(c)(2)(ii)) in Tier III (Figure 3-2). Current WQC for the protection of marine life can be obtained from the U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Standards Branch (WH-585), 401 M Street S.W., Washington, DC 20460.

For benthic evaluations, there is not widespread agreement that any single dredged-material evaluation procedure fully satisfies the objective of and is suitable for use in Tier II. When technically sound sediment quality criteria (SQC) are developed and the corresponding Final Notice of Availability is published in the *Federal Register* by EPA, these criteria will be incorporated into Tier II benthic-impact evaluations. The incorporation of these criteria into Tier II will be implemented by the insertion of a new Section into this testing manual. This new Section will be developed jointly by EPA and the USACE. It will provide guidance on how to use the SQC to determine compliance with the limiting permissible concentration (LPC).

At present, only the bioaccumulation impact of nonpolar organic compounds in dredged material on benthic organisms can be evaluated in Tier II (Figure 3-3). The approved procedure calculates the theoretical bioaccumulation potential (TBP) for a test organism by factoring the concentrations of the nonpolar organic chemical and the total organic carbon (TOC) in the sediment and the percent lipid concentration (%L) in the organism. This calculation predicts the magnitude of bioaccumulation likely to be associated with nonpolar organic contaminants in the dredged material.

5.1 WATER-COLUMN EVALUATIONS

Program experience has shown that in most cases the existing data are sufficient to make water-column LPC determinations. However, Tier I evaluation may show that the existing information is insufficient to evaluate LPC compliance. In this case, paragraph 227.13(c) of the regulations (Appendix A) requires testing to determine the potential for water-column impact and whether the corresponding LPC is met. This evaluation is performed under Tier II. If a WQC LPC decision cannot be made in Tier I, Tier II evaluation is mandatory even if subsequent evaluations are to be conducted in Tiers III and IV (Figure 3-2). Under no circumstances can the disposal of the dredged material cause the applicable marine WQC to be exceeded outside the disposal site at any time or within the site after the 4-h initial-mixing period. The WQC evaluation in Tier II can be bypassed only if there are no WQC for any of the contaminants in the dredged material.

The Tier II water-column evaluation for WQC is a two-step process, using the numerical model provided in Appendix B. The first step uses the model as a screen and assumes that all of the contaminants in the dredged material are released into the water column during the disposal process. The second step applies the same model with results from chemical analysis of the elutriate test.

5.1.1 Step 1: Screen To Determine WQC Compliance

Step 1 of the Tier II water-column evaluation comprises a screen that assumes that all of the contaminants in the dredged material are released into the water column during the disposal operation (Section 10.1.1). This is a conservative assumption because, in virtually all cases except at extremely deep disposal sites, most of the contaminants remain within the dredged material that settles to the bottom. If the numerical model (Appendix B) predicts that the concentration of all contaminants of concern released into the water are less than the applicable WQC and if no synergistic effects are suspected, the dredged material meets the LPC for the water column. If the screen/model, as applied in Step 1, indicates that the LPC is exceeded, Step 2 is employed, as described in Section 5.1.2. If WQC have not been established for all contaminants of concern or if synergistic effects are suspected, further testing in Tier III is required to determine compliance with the LPC for the water column (Section 6.1).

5.1.2 Step 2: Elutriate Analysis To Determine WQC Compliance

If additional water-column testing of dredged material is determined to be necessary after completion of the screen (Section 5.1.1), the regulations (Appendix A) are very specific about tests to be performed and the criteria to be met.

> **§ 227.13**
>
> **(c)** . . . dredged material can be considered to be environmentally acceptable for ocean dumping only under the following conditions:
>
> **(1)** The material is in compliance with the requirements of § 227.6; and
>
> **(2)(i)** All major constituents of the liquid phase are in compliance with the applicable marine WQC after allowance for initial mixing; or
>
> **(ii)** When the liquid phase contains major constituents not included in the applicable marine WQC, or there is reason to suspect synergistic effects of certain contaminants, bioassays on the liquid phase of the dredged material show that it can be discharged so as not to exceed the limiting permissible concentration as defined in paragraph (a) of § 227.27. . .
>
> **(3)(d)** For the purposes of paragraph (c)(2) of this section, major constituents to be analyzed in the liquid phase are those deemed critical by the District Engineer, after evaluating and considering any comments received from the Regional Administrator, and considering known sources of discharges in the area.

In Step 2, the numerical mixing model (Appendix B) is run with chemical data obtained from an elutriate test conducted on the dredged material. The standard elutriate analysis is described in Section 10.1.2.1 and the analytical procedures for measuring constituents in the water are presented in Section 9.4.2. The modeling is, in effect, using data that more accurately represent the contaminant concentrations that will be present in the water column at the disposal site. If the numerical model (Appendix B) predicts that the concentration of all contaminants of concern in the water column are less than the applicable WQC and if no synergistic effects are suspected, the dredged material meets the LPC for the water column. If the model run shows that the WQC are exceeded, the LPC for the water column is not met.

5.1.3 Water-Column Toxicity Compliance

At present, there is no procedure to assess LPC compliance for water-column toxicity in Tier II for dredged-material contaminants without WQC or from effects of synergistic reactions (Figure 3-2). If WQC have not been established for all contaminants of concern or if synergistic effects are expected, further testing in Tier III is required to determine water-column LPC

compliance. Consequently, toxicity evaluations and LPC determinations for these situations must take place in Tier III or IV. As a rule, *synergistic effects are to be suspected wherever there is more than one contaminant present in the sediment.*

In Tier II, one of three possible conclusions is reached regarding the toxicity of the proposed dredged material.

- Concentrations of all of the dissolved contaminants of concern in the dredged material, after allowance for initial mixing, do not exceed the applicable marine WQC beyond the boundaries of the disposal site at any time nor exceed the WQC anywhere in the marine environment 4 h after dumping. Additionally, synergistic effects from more than one contaminant of concern are not anticipated. Therefore , the dredged material complies with applicable WQC requirements of paragraph 227.13(c)(2)(i) and the LPC requirements for the water column of paragraph 227.13(c)(2)(ii). If so, no further information is necessary to determine compliance with the regulations regarding water-column impact, but benthic impact has to be evaluated. If the information warrants, it is acceptable to determine compliance with water-column effects criteria of paragraphs 227.13(c)(2)(i) and 227.13(c)(2)(ii) at Tier II and determine compliance with benthic effects criteria at another tier.
- The WQC requirements are met but one or more of the contaminants of concern do not have established marine WQC and/or synergistic effects of the contaminants are suspected. Therefore, determination of compliance with water-column effects criteria is not possible and water-column toxicity must be evaluated in Tier III or IV.
- Concentrations of one or more of the dissolved contaminants of concern, after allowance for initial mixing, exceed applicable marine WQC beyond the boundaries of the disposal site or exceed marine WQC within the site after the first 4 h. In this case, the dredged material does not comply with the WQC requirements of paragraph 227.13(c)(2)(i) and the LPC is exceeded.

5.2 BENTHIC IMPACT

As discussed above, the currently available Tier II procedure for evaluating potential benthic impact consists of evaluating the TBP. The TBP is calculated according to the guidance in Section 10.2. At present, this calculation can be performed for nonpolar organic compounds, but not for polar organic compounds, organometals, or metals. If such constituents are contaminants of concern in a dredged material requiring bioaccumulation evaluation, that evaluation has to take place in Tiers III and/or IV.

In the Tier II benthic-impact evaluation, a comparison is made between TBP calculated for the nonpolar organic contaminants of concern in dredged material and for the same constituents in the reference sediment. *If all the contaminants of concern in the dredged material are nonpolar organics,* one of the following conclusions is reached based on this comparison:

- The TBP for the nonpolar organic contaminants of concern in the dredged material does not exceed the TBP for the reference sediment and, therefore, the dredged material complies with bioaccumulation aspects of the benthic criteria in paragraph 227.13(c)(3). If so, no further information is necessary to determine compliance with the bioaccumulation regulations, but biological effects also have to be considered to determine compliance with the benthic criteria in paragraph 227.13(c)(3) (Appendix A). If the information warrants, it is acceptable to determine compliance with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) at Tier II, and determine compliance with the biological-effects aspects of the benthic criteria at another tier. Potential water-column impact also has to be considered.
- The TBP for the contaminants of concern in the dredged material exceeds the TBP for the reference sediment. In this case, the information is not sufficient to determine whether the dredged material complies with the bioaccumulation aspects of the benthic criteria in paragraph 227.13(c)(3), and further evaluation of bioaccumulation in Tiers III and/or IV is appropriate. Potential water-column impact also has to be considered.

Although the calculation of TBP is used to evaluate nonpolar organic compounds in Tier II, a particular dredged material may contain contaminants of concern for which it may be inappropriate to make this calculation. For these contaminants, bioaccumulation has to be evaluated in Tiers III and/or IV. However, even if the dredged material contains other contaminants of concern in addition to nonpolar organic contaminants of concern, it is still useful to calculate the TBP. The TBP provides an indication of the magnitude of bioaccumulation of nonpolar organics that may be encountered in Tiers III and/or IV testing. Additionally, if the TBP of the nonpolar organics meets the decision guidance in this section, the calculation may eliminate the need for further evaluation of these compounds and thereby reduce efforts in Tiers III and/or IV.

6.0 TIER III EVALUATION

Tier III testing assesses the impact of contaminants in the dredged material on appropriate sensitive organisms to determine if there is potential for the dredged material to have an unacceptable impact. The Tier III assessment methods are bioassays and bioaccumulation tests (Figures 3-1 through 3-3). When sublethal chronic-effects tests are developed and approved by EPA and the USACE, they will be included in this tier.

Tier III bioassays use lethality as the endpoint because lethality is easily interpreted and quantified. The bioassays are acute tests using organisms representative of the water-column and benthic environments at the disposal site. The recommended procedures for water-column bioassays (Figure 3-2) use appropriate sensitive marine water-column organisms (Section 11.1.1, Table 11-1). The assay for benthic impact (Figure 3-3) uses deposited sediment and appropriately sensitive benthic marine organisms (Section 11.2.1, Table 11-2).

Bioaccumulation also has to be considered to fully evaluate potential benthic impact (Figure 3-3). The results of bioaccumulation tests are used to predict the potential for uptake of dredged-material contaminants by organisms (Biddinger and Gloss, 1984; Kay, 1984). These tests may be conducted in the laboratory (Section 12.1). The Tier III information is usually sufficient for decision-making, or it may, in rare cases, indicate that further information on toxicity or bioaccumulation (or both) is required at Tier IV.

6.1 WATER-COLUMN BIOASSAYS

If additional water-column testing has been shown to be necessary (Section 5.1), the Tier III water-column evaluation (Figure 3-2) considers the effects, after allowance for initial mixing, of dissolved contaminants plus those associated with suspended particulates on water-column organisms. According to paragraph 227.13(c)(2)(ii) of the regulations (Appendix A), water-column bioassays must be used when there are not applicable marine water-quality criteria (WQC) for all the contaminants of concern or when there is reason to suspect the synergistic effects of certain contaminants. The bioassay and initial-mixing data results are generated as described in Section 11.1. The limiting permissible concentration (LPC) is defined in paragraph 227.27(a)(2) (Appendix A) as

> *That concentration of waste or dredged material in the receiving water which, after allowance for initial mixing, as specified in § 227.29, will not exceed a toxicity threshold defined as 0.01 of a concentration shown to be acutely toxic to appropriate sensitive*

marine organisms in a bioassay carried out in accordance with approved EPA procedures.

After considering this requirement, one of the following conclusions is reached.

- The concentration of dissolved plus suspended contaminants, after allowance for initial mixing, does not exceed 0.01 of the acutely toxic concentration beyond the boundaries of the disposal site within the first 4 h after dumping or at any point in the marine environment after the first 4 h. Therefore, the dredged material complies with the water-column toxicity criteria of paragraphs 227.13(c)(2)(ii) and 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with the regulations regarding water-column impact, but benthic impact has to be considered. If the information warrants, it is acceptable to determine compliance with the water-column effects criteria of paragraphs 227.13(c)(2)(ii) and 227.13(c)(3) at Tier III and determine compliance with the benthic effects criteria at another tier.
- The concentration of dissolved plus suspended contaminants, exceeds 0.01 of the acutely toxic concentration beyond the boundaries of the disposal site at any time and/or within the disposal site after the 4-h initial-mixing period. Therefore, the dredged material does not meet the water-column LPC as defined in paragraph 227.13(c)(2)(ii) or in paragraph 227.13(c)(3) (Appendix A).

6.2 WHOLE-SEDIMENT BIOASSAYS

Evaluation of benthic bioassays in Tier III (Figure 3-3) is based on data generated according to the guidance in Section 11.2. For benthic-effects evaluation, the LPC of the solid phase of dredged material is applicable and is defined in paragraph 227.27(b) (Appendix A) as

> . . . *that concentration which will not cause unreasonable acute or chronic toxicity or sublethal adverse effects based on bioassay results using . . . appropriate sensitive benthic marine organisms* . . . .

Dredged material does not meet the LPC for benthic toxicity when bioassay organism mortality (1) is statistically greater than in the reference sediment and (2) exceeds mortality in the reference sediment by at least 10%.* (or a value that is in accordance with approved testing methods, e.g., 20% for amphipod bioassays). The 10% value should be used unless another value is approved for use. If values other than 10% are to be used, they should be derived for each test species and test endpoint. The data supporting the values should meet quality-assurance (QA) standards and provide an adequate basis for regulation.

*This value may be replaced in local guidance if there is a scientific basis for the change. The present EPA/USACE recommendation is that a value of 20% be used for amphipod tests. This recommendation is based on the inherent variability of these tests. If test refinement can reduce this variability, the percentage will be correspondingly reduced to enable more accurate evaluations of the results.

After considering this guidance, one of the following conclusions is reached for the acute toxicity of contaminants in the dredged material in Tier III.

- Mortality in the dredged material is not statistically greater than in the reference sediment, or does not exceed mortality in the reference sediment by at least 10%. Therefore, the dredged material meets the LPC for benthic toxicity and complies with the benthic bioassay criteria of paragraph 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with the LPC for benthic toxicity, but bioaccumulation also has to be considered under paragraph 227.13(c)(3). If the information warrants, it is acceptable to determine compliance with the benthic-bioassay criteria of paragraph 227.13(c)(3) at Tier III and with the bioaccumulation criteria of paragraph 227.13(c)(3) at another tier. Potential water-column impact also has to be considered.
- Mortality in the dredged material is statistically greater than in the reference sediment and exceeds the mortality in the reference sediment by at least 10%.* In this case, the dredged material exceeds the LPC and does not comply with the benthic bioassay criteria of paragraph 227.13(c)(3) (Appendix A).

6.3 BIOACCUMULATION BY BENTHOS

Bioaccumulation potential, as well as toxicity, has to be in compliance with the regulations before a dredged material can be considered acceptable for ocean dumping. The Tier III benthic-bioaccumulation tests provide for the determination of bioavailability through 10-day exposure tests if all contaminants of concern are metals or 28-day exposure tests if any contaminants of concern are organic or organometallic compounds. Information for evaluating bioaccumulation potential in Tier III for each of the contaminants of concern is presented in Section 12.1. Identification of the specific contaminants of concern in each dredged material is discussed in Section 4.2.

Bioaccumulation of most compounds, if it occurs, will be detectable after the Tier III 10- or 28-day exposure period, even though the steady state may not have been reached. Thus, while the Tier III tests may not determine steady-state bioaccumulation, they provide useful information about the potential for bioaccumulation (i.e., bioavailability).

Concentrations of contaminants of concern in tissues of benthic organisms following 10- or 28-day exposure to the dredged material are compared initially against applicable Food and Drug Administration (FDA) Action Levels for Poisonous or Deleterious Substances in Fish and Shellfish for Human Food, when such levels (i.e., limits) have been set for the contaminants. These action levels are the limits above which the FDA can take legal action to remove products from the market. The levels, which are based on human-health as well as economic considerations, are revised according to the criteria specified in 21 CFR 109 and 509. They do

not include the potential for environmental impact on the contaminated organisms or on their nonhuman predators. The current FDA action levels are listed in Table 6-1. Updated lists may be obtained from the Food and Drug Administration, Center for Food Safety and Applied Nutrition, Industry Programs Branch, Bureau of Foods (HFF-326) 200 C Street S.W., Washington DC 20204; (202) 485-0020.

Because contamination of seafood in excess of FDA levels is considered a threat to human health, the guidance in this manual is that concentrations in excess of FDA levels in any test species may be considered unacceptable. This guidance applies even though the test species may not be a typical human food item because contaminants can be transferred through aquatic food webs, and uptake to FDA levels in one species indicates the potential for accumulation in other species. FDA action levels do not consider ecological impact; however, for the purposes of this manual, they serve as an upper limit of acceptability.

Based on the comparison against FDA levels, one of the following conclusions is reached.

- Tissue concentrations of one or more contaminants of concern are statistically greater than applicable FDA action levels. Therefore, the dredged material exceeds the limiting permissible concentration (LPC) for bioaccumulation and does not comply with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A).
- Tissue concentrations of all contaminants of concern either are not statistically greater than applicable FDA action levels or there are no FDA levels for the contaminants of concern. In this case, the information is insufficient to determine compliance with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A), and the dredged material has to be further evaluated in Tier III as described below for bioaccumulation potential before a decision can be made.

Concentrations of contaminants determined in tissues of organisms following the 10- or 28-day exposure to dredged material and less than FDA action levels or in the absence of FDA levels are compared to contaminant concentrations in tissues of organisms similarly exposed to reference sediment. One of the following conclusions is reached based on this comparison.

- Tissue concentrations of contaminants of concern in organisms exposed to dredged material do not statistically exceed those of organisms exposed to the reference sediment, and therefore the dredged material meets the LPC for bioaccumulation and complies with the benthic criteria of paragraph 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with bioaccumulation regulations, but benthic-toxicity effects also have to be considered to determine compliance with the benthic criteria of paragraph 227.13(c)(3). Potential water-column impact also has to be considered.

Table 6-1 Food and Drug Administration (FDA) Action Levels for Poisonous and Deleterious Substances in Fish and Shellfish for Human Food[a]

Substance	Action Level[b]
Metals	
Methyl Mercury	1.0 ppm
Pesticides	
Benzene Hexachloride (BHC)	0.3 ppm
Chlordane	0.3 ppm
Chlordecone (Kepone)	0.3 ppm
DDT + DDE	5.0 ppm
Dichlorophenoxyacetic acid	1.0 ppm
Dieldrin + Aldrin	0.3 ppm
Endrin	0.3 ppm
Fluridone	0.5 ppm
Heptachlor + Heptachlor Epoxide	0.3 ppm
Hexachlorobenzene (HBC)	0.3 ppm
Isopropylamine	0.25 ppm
Mirex	0.1 ppm
Simazine	12.0 ppm
Toxaphene	5.0 ppm
Industrial Chemicals	
PCBs	2.0 ppm
Dioxin	25.0 ppt

[a]Action levels are established, revised, and revoked through notices published in the *Federal Register.* It is the responsibility of the users of this list to keep up to date on any amendments to this list. For further information on current action levels, users may contact the Food and Drug Administration, Center for Food Safety and Applied Nutrition, Industry Programs Branch [HFF-326, 200 C Street, S.W., Washington, DC 10204; (202) 485-0020].

[b]Action levels are reported in wet weight.

- Tissue concentrations of contaminants of concern in organisms exposed to dredged material statistically exceed those of organisms exposed to the reference material. In this case, it is recommended that the EPA Regional Administrator and the USACE District Engineer develop and agree upon case-specific evaluative criteria, based on technical evaluations made with local input, that emphasize the various factors deemed appropriate in each area for determining compliance with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A).

To determine compliance with paragraph 227.13(c)(3), when the bioaccumulation of contaminants in dredged-material tests statistically exceeds that in the reference-material tests, the following factors should be assessed to evaluate LPC compliance.

- Number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material
- Number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material
- Magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material
- Toxicological importance of the contaminants whose bioaccumulation from the dredged material statistically exceeds that from the reference material
- Phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material
- Propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs (Biddinger and Gloss, 1984; Kay, 1984)
- Magnitude of toxicity and number and phylogenetic diversity of species exhibiting greater mortality in the dredged material than in the reference material
- Magnitude by which contaminants whose bioaccumulation from the dredged material exceeds that from the reference material also exceed the concentrations found in comparable species living in the vicinity of the proposed disposal site.

These and perhaps other factors are complexly interrelated; i.e., the acceptable level of each factor depends on its interaction with all other factors. These factors have to be considered in developing case-specific criteria (if needed) for dredged material assessed for bioaccumulation in the final step of Tier III. After considering these factors, one of the following decisions is reached.

- Dredged material meets the LPC for bioaccumulation and complies with the benthic criteria of paragraph 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with bioaccumulation regulations, but toxicity and water-column effects also have to be considered to determine compliance with paragraph 227.13(c).
- Dredged material exceeds the LPC for bioaccumulation and does not comply with the benthic criteria of paragraph 227.13(c)(3) (Appendix A) and the LPC is not met.

- Information is insufficient to evaluate the LPC for bioaccumulation or to determine compliance with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A). Further evaluation of steady-state bioaccumulation in Tier IV is necessary to evaluate compliance.

6.4 REFERENCES

Biddinger, G.R., and Gloss, S.P. 1984. The importance of trophic transfer in the bioaccumulation of chemical contaminants in aquatic ecosystems. Residue Rev. 91:104-130.

Kay, S.H. 1984. Potential for biomagnification of contaminants within marine and freshwater food webs. Tech. Rep. D-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

7.0 TIER IV EVALUATION

Where a decision regarding toxicity or bioaccumulation has not been reached at earlier (i.e., lower-numbered) tiers or where circumstances warrant, Tier IV evaluations (Figure 3-1) are used to determine compliance with paragraph 227.13(c) (Appendix A). Tier IV tests consist of bioassays and bioaccumulation tests to determine the long-term effects of exposure to dredged material. Tier IV tests may be conducted for water-column evaluations (Figure 3-2) or benthic evaluations (Figure 3-3). In either case, Tier IV tests should be carefully selected to address the specific issues relevant to the case in question. Whatever the Tier IV test, the case-specific evaluative criteria for these tests have to be determined beforehand and agreed upon by EPA and the USACE, and have to be adequate to determine compliance with the requirements of paragraph 227.13(c).

7.1 BIOASSAYS

Tier IV bioassays should measure sensitive indicators of long-term effects of clear ecological importance, such as survival, reproduction, and, perhaps, the time to the onset of reproduction. Tier IV bioassays might be of longer duration than the Tier III tests, and might simulate the exposure conditions expected at the disposal site. Tier IV bioassays of deposited dredged material should maximize exposure to sediment-associated contaminants by focusing on infaunal organisms.

Because of the limited availability of appropriate and widely accepted procedures for Tier IV bioassays, these tests should be carefully selected to address the specific needs of each dredged-material disposal operation. Tier IV tests should be designed to provide more detailed information about the effects of exposure to the dredged material than does Tier III testing. Tier IV testing might be appropriate when the evidence is sufficient to require testing for carcinogens, mutagens, or teratogens under paragraph 227.13(c) of the regulations.

Tier IV allows generation of appropriate information about the proposed disposal operation when there is no other option for the generation of additional information. As discussed previously, even with the development of appropriate and acceptable new test procedures, including those for chronic exposure, it is anticipated that the case-by-case design and implementation of tests will continue to be a necessary component of Tier IV evaluations.

Case-specific evaluative criteria have to be developed for interpreting the results of Tier IV bioassays. These criteria have to be adequate to determine compliance with the requirements of paragraph 227.13(c) of the regulations.

7.2 BIOACCUMULATION BY BENTHOS

When a decision cannot be reached on the basis of the 10- or 28-day bioavailability data, it is appropriate to determine steady-state bioaccumulation of the contaminants of concern in Tier IV (Figure 3-3). Tissue samples used for this evaluation may be collected in the field (Section 12.2.2) or be generated by laboratory exposure of test organisms to the dredged material (Section 12.2.1). As with the Tier III evaluation of bioavailability from the 10- or 28-day tests, the first step in the evaluation of steady-state bioaccumulation is the comparison of steady-state concentrations of contaminants of concern to Food and Drug Administration (FDA) Action Levels for Poisonous or Deleterious Substances in Fish and Shellfish for Human Food. Following this comparison, one of the following conclusions is reached.

- Tissue concentrations of one or more contaminants of concern are statistically greater than applicable FDA action levels. Therefore, the dredged material exceeds the limiting permissible concentration (LPC) for bioaccumulation and does not comply with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A).
- Tissue concentrations of all contaminants of concern either are not statistically greater than applicable FDA action levels or there are no FDA levels for the contaminants of concern. In this case, the information is insufficient to determine compliance with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A), and the dredged material has to be further evaluated in Tier III as described below for bioaccumulation potential before a decision can be made.

Steady-state tissue concentrations of contaminants of concern that do not statistically exceed FDA action levels are next compared to steady-state concentrations of these contaminants that were determined in organisms exposed to reference sediment. Based on this comparison, one of the following conclusions is reached.

- Steady-state concentrations in organisms exposed to dredged material are determined not to statistically exceed those of organisms exposed to reference sediment, and therefore the dredged material meets the LPC bioaccumulation and complies with the bioaccumulation aspects of the benthic criteria in paragraph 227.13(c)(3) (Appendix A). No further information is necessary to determine compliance with the bioaccumulation regulations; however, benthic toxicity effects also have to be considered to determine compliance with paragraph 227.13(c). Potential water-column effects also have to be considered.

- Steady-state concentrations in organisms exposed to dredged material statistically exceed those of organisms exposed to reference sediment. In this case, the information is insufficient to evaluate the LPC or to determine compliance with the benthic criteria of paragraph 227.13(c)(3) (Appendix A), and further evaluation of steady-state bioaccumulation in Tier IV is necessary.

Steady-state contaminant concentrations in tissue samples that exceed those of organisms exposed to reference sediment are compared against contaminant concentrations in field-collected benthic organisms (Figure 3-3), as described in Section 12.2.2.4. Field-collected organisms (preferably the same species as those used for the laboratory analysis) are those collected in the vicinity of the proposed disposal site and provide an indication of the steady-state body burden of the contaminants of concern around the site. One of the following conclusions is reached.

- The steady-state bioaccumulation of contaminants of concern does not statistically exceed the concentration of these contaminants in field-collected organisms, and therefore the dredged material complies with the bioaccumulation aspects of the benthic criteria in paragraph 227.13(c)(3) (Appendix A). If so, the LPC for bioaccumulation is met and no further information is necessary to determine compliance with the bioaccumulation regulations, but benthic-toxicity effects must also be considered to determine compliance with paragraph 227.13(c). Potential water-column effects also have to be considered.
- The steady-state bioaccumulation of contaminants statistically exceeds that of the field organisms. In this case, it is desirable that the EPA Regional Administrator and the USACE District Engineer develop and agree upon case-specific evaluative criteria, based on technical evaluations made with local input, that emphasize the various factors deemed appropriate in each area for determining compliance with the benthic criteria of paragraph 227.13(c)(3) (Appendix A).

In evaluating bioaccumulation potential to determine compliance with paragraph 227.13(c) where the steady-state bioaccumulation of contaminants of concern exceeds that of the field organisms, concern over potential adverse impact increases in direct relation to the

- Number of species in which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material
- Number of contaminants for which bioaccumulation from the dredged material is statistically greater than bioaccumulation from the reference material
- Magnitude by which bioaccumulation from the dredged material exceeds bioaccumulation from the reference material
- Toxicological importance of the contaminants whose bioaccumulation from the dredged material statistically exceeds that from the reference material
- Phylogenetic diversity of the species in which bioaccumulation from the dredged material statistically exceeds bioaccumulation from the reference material
- Propensity for the contaminants with statistically significant bioaccumulation to biomagnify within aquatic food webs (Biddinger and Gloss, 1984; Kay, 1984)

- Magnitude of toxicity and number and phylogenetic diversity of species exhibiting greater mortality in the dredged material than in the reference material
- Magnitude by which contaminants whose bioaccumulation from the dredged material exceeds that from the reference material also exceeds the concentrations found in comparable species living in the vicinity of the proposed disposal site.

These and perhaps other factors are complexly interrelated; i.e., the acceptable level of each factor depends on its interaction with all other factors. These factors have to be considered in developing case-specific criteria (if needed) for dredged material assessed for bioaccumulation in the final step of Tier IV. After considering these factors, one of the following decisions is reached.

- The dredged material meets the LPC for bioaccumulation and complies with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A). If so, no further information is necessary to determine compliance with bioaccumulation regulations, but toxicity and water-column effects also have to be considered to determine compliance with paragraph 227.13(c).
- The dredged material exceeds the LPC for bioaccumulation and does not comply with the bioaccumulation aspects of the benthic criteria of paragraph 227.13(c)(3) (Appendix A).

7.3 REFERENCES

Biddinger, G.R., and Gloss, S.P. 1984. The importance of trophic transfer in the bioaccumulation of chemical contaminants in aquatic ecosystems. Residue Rev. 91:104-130.

Kay, S.H. 1984. Potential for biomagnification of contaminants within marine and freshwater food webs. Tech. Rep. D-84-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Part III

DATA GENERATION

8.0 COLLECTION AND PRESERVATION OF SAMPLES

If it is determined that physical, chemical, and biological testing is necessary (certain dredging operations may require no sampling), samples of dredged material, reference sediment, control sediment, organisms, and water will need to be collected. These are used for chemical analysis, bioassays, and bioaccumulation tests. This Section provides guidance for the development of a sampling plan that will lead to the collection, preservation, and storage of representative sediment, water, and organism tissue samples so that the physical and chemical characteristics and potential toxicity and bioaccumulation of dredged material can be accurately assessed.

Sampling is the foundation upon which all testing rests. Therefore, regional guidance is important for developing project-specific sampling plans. There are so many case-specific factors that influence sampling needs that detailed guidance of National scope is impractical. Table 8-1 represents the type of samples that may be required to complete the evaluations of Tiers II, III, and IV. This manual provides general guidance on items of major importance to consider when designing a sampling plan. The guidance focuses on two aspects of sampling design. One aspect is directed toward the project managers and administrative personnel who determine what tests are to be run and where and how samples are to be collected, handled, and tested. The second aspect, discussed later in this Section, concerns the technical details of sample collection and preservation.

8.1 BACKGROUND FOR A SAMPLING PLAN

A well-designed sampling plan is essential when evaluating the potential impact of dredged material discharge upon the marine environment. Before any sampling is initiated, the sampling plan has to be tailored to meet clearly defined objectives for individual dredging operations. In designing a generalized sampling program, factors such as the availability and content of historical data, the degree of sediment heterogeneity, the number and geographical distribution of sample-collection sites, the procedures for collection, preservation, storage, and tracking of samples, and the necessity for adequate quality assurance and quality control have to be carefully considered. The magnitude of the dredging operation and its time and budgetary constraints should also be considered.

Table 8-1. Sample-Collection Requirements.
This table contains general guidance on the type of samples that may be required to be collected from the field to conduct dredged-material evaluation tests. Actual sampling requirements are project-specific and are determined during the development of the project plan based on the guidance provided in this manual and in regional testing manuals.

Tests	Water Samples			Sediment Samples		
	Disposal Site	Dredging Site	Control[a]	Dredging Site	Reference Site	Control[a]
Tier II						
Water column						
Screen	•			•		
Elutriate	•	•		•		
Tier II						
Benthic				•	•	
Tier III						
Water column	•[b]	•	•	•		
Tier III						
Benthic				•	•	•
Tier IV						
Water column	•	•	•	•		
Tier IV						
Benthic				•	•	•

[a]May or may not have to be field-collected

[b]Dilution water; artificial or clean seawater (see Section 11.1.4)

An acceptable sampling plan should be in place before sampling begins. An adequate amount of sediment and water should be collected to conduct planned evaluations. Careful consideration of maximum allowable and recommended holding times for sediments as well as the exigencies of resampling should be given careful consideration.

The importance of sampling is underscored by the fact that any evaluation is only as complete and reliable as the sampling (and sample handling and storage) upon which it is based. Thus, inadequacies or biases in sampling will manifest themselves by limiting the accuracy and/or the appropriateness of the study results.

The objective is to obtain samples to characterize the dredging and reference-material area. Sample size should be small enough to be conveniently handled and transported but large enough to meet the requirements for all planned analyses. The quality of the information obtained through the testing process is impacted by the following three factors.

- Collecting representative samples
- Using appropriate sampling techniques
- Protecting or preserving the samples until they are tested.

Ideally, the importance of each of the three factors will be fully understood and appropriately implemented for each study. In practice, however, this is not always the case. There may be occasions when study needs, time, or other resource constraints will limit the amount of information that should or can be gathered. When this is the case, each of these factors has to be carefully considered in light of the specific study purposes when designing a sampling plan.

An important component of any field sampling program is a preproject meeting with all concerned personnel. Attendants may include management, field personnel, laboratory personnel, data management/analysis personnel, and representatives of the regulators and the dredging proponent. The purposes of the meeting include (1) defining the objectives of the sampling program and (2) ensuring communication among participating groups.

Samples are collected and tested or analyzed to gain information. To be most useful, the information generated through a sampling program has to be directed at a specific need. The purposes of defining the objectives of a sampling program should be to clarify the information needed and to match these needs with the specific tests that supply the required information.

The stated objectives of a testing program should be more specific than just stating, for example, "An environmental evaluation of a proposed dredged material disposal operation."

Although an environmental assessment may be the overall objective, the objectives of the testing program should be stated as specific tasks, such as

- Compare one or more sites in the dredging area with the reference area
- Determine the kind and/or distribution of chemical contaminants in the sediments of a dredging area
- Determine potential sediment toxicity
- Determine bioaccumulation potential.

The more explicitly the goals of a testing program can be stated, the easier it will be to design an appropriate sampling plan. When the sampling plan is completed, to select the appropriate methods of preservation, all sampling procedures should be clearly defined, sample volumes should be clearly established, all logistical concerns should be fully addressed, and target analytes should be identified to class of compound.

8.2 COMPONENTS OF A SAMPLING PLAN

A sampling plan that meets the stated objectives has to cover certain issues. The following steps are a guideline to ensure that all essential information is provided.

- Review the engineering specifications for the dredging operation, including the dimensions of the dredging area, the dredging depth(s), and the volume of sediment for disposal.
- Evaluate the prior history and the existing database for the area. Identify relevant data and the need for additional data. Identify areas of potential environmental concern within the confines of the dredging operation.
- If appropriate, subdivide the dredging area into project segments on the basis of an assessment of level of environmental concern within the dredging area. This may be an iterative process that starts before sampling, using available information, and that is refined after sampling, based on new data.
- Determine the number of samples to be collected and select sampling locations. Choose methods and equipment for positioning vessels at established stations.
- Determine what sampling methods will be used.
- Define procedures for sample handling, preservation, and storage.
- Identify potential logistical problems and define safety precautions.
- Prepare a quality assurance/quality control plan.

The subsections that follow discuss each of these steps and provide general guidance for their conduct. Supplemental guidance on basic sampling considerations generally applicable to dredged material is discussed from a quality assurance perspective by EPA (1987).

8.2.1 Review of Dredging Specifications

A review of the engineering specifications for the dredging operation provides a general overview to serve as a basis for designing a sampling plan. The volume of material to be dredged and the method of dredging are two of several important factors used to determine the number of samples required. Knowledge of the thickness and physical characteristics of the material to be dredged will help to determine the kind of sampling equipment that is required. The boundaries of the dredging area have to be known to ensure that the number and location of samples are appropriate.

8.2.2 Historical Data

In developing a sampling plan, it is important to review all information relevant to the dredging site. Using pertinent available information to determine project segments and station locations within the dredging area can produce significant cost savings over researching for new data. Reviewing historical data is the first step in determining whether sediment might be contaminated. If the review identifies possible point sources of contamination, skewing the sampling effort toward these areas may be justified for thorough characterization of the potentially contaminated areas. On the other hand, increasing the proportion of samples in contaminated areas relative to other areas may lead to the conclusion that the socalled average contamination is higher than purported. To reduce problems in areas of unequally distributed contamination, the total sampling effort should be increased. The information gathered for the Tier I evaluation (discussed in Section 4.1) should be reviewed for assistance in designing the sampling plan.

A review of historical information should include the following.

- **Geotechnical, geochemical, and hydrodynamic data**
  The grain size, specific density, water content, and identification of sediment horizons are helpful in making operational decisions. Areas of high tidal currents and high wave energy tend to have larger grain-sized sediments than do quieter areas. Contaminants have a greater affinity for clay and silt than for sand. The available data should be consulted to examine the horizontal and vertical particle-size distribution.

- **Quality and age of available data**
  The value of the available data should be critically weighed. Existing high-quality data might lower costs by reducing the number of analytes measured or tests required for the proposed dredging operation. Even data that do not meet all current quality- assurance standards can sometimes provide useful general

information about the operation. For example, there may have been significant improvements in sampling and analytical methods since the original study, or the original chain-of-custody or documentation procedures may have been inadequate. Information from such studies might be helpful in identifying areas of contamination, but not in accurately assessing the degree of contamination.

- **Spill data**
  Evidence of a contaminant spill within or near the area of the dredging may be an important consideration in identifying areas for sampling.

- **Dredging history**
  Knowledge of prior dredging may dramatically affect sampling plans. If the area is frequently dredged (every 1-2 years) or if the sediments are subject to frequent mixing by wave action or ship traffic, the sediments are likely to be relatively homogenous. Assuming that there is no major contaminant input, the sampling effort may be minimal. However, if there is information regarding possible contamination, a more extensive sampling effort may be indicated. New excavations of material unaffected by anthropogenic input may require less intensive sampling for contaminants than does maintenance dredging.

8.2.3 Subdivision of Dredging Area

Sediment characteristics are likely to vary substantially within the limits of the area to be dredged as a result of geographical and hydrological features in the area. Areas of low hydraulic energy will be characterized by fine sediments that have a greater tendency to accumulate contaminants than do coarser-grained sediments. Sediments in heavily urbanized or industrialized areas are more likely to accumulate contaminants than do sediments farther removed from direct contaminant input.

Many dredging operations can be subdivided into project segments for sampling. A project segment is an area expected to have relatively consistent characteristics that differ substantially from the characteristics of adjacent segments. Project segments may be sampled with various intensities, and, if warranted by objectives of the study and test results, the dredged material from various project segments can be managed in different manners during dredging and disposal to limit environmental impact. When the sampling plan is developed, project segments can be designated, based on historical data, sediment characteristics, geographical configuration, depth of cut, sampling- or dredging-equipment limitations, results of pilot studies, known or suspected contaminant concentrations, etc. Surface sediments might be considered as a project segment that is separate from subsurface sediments at the same location if vertical stratification of contamination is expected. Large dredging operations located within industrialized areas might require subdivision into several project segments horizontally and into one or

more segments vertically. A dredging operation characterized by relatively uniform distribution of sediment type in a nonindustrialized location might be considered as a single project segment. Vertical subdivisions usually are not appropriate in areas of rapid shoaling or in areas of high sediment mixing by ship scour. These areas are likely to be relatively homogenous vertically. Vertical subdivisions smaller than about 2-3 ft are impractical because a dredge operator cannot reliably control excavation with any finer precision. If analytical data or test results for two or more project segments prove to be similar, these segments should be treated as one large segment when considering disposal options. If the analytical and test results demonstrate important differences between project segments, an alternative disposal option may be necessary for a portion of the total sediment volume.

Any established sampling program should be sufficiently flexible to allow changes based on field observations. Certain characteristics of the sediments, such as color or texture, can be an indication of patchiness to the field crew chief. The greater the patchiness, the larger the number of samples that will be required to define the area. The project manager can refine a sampling program based on historical data and/or a preliminary sampling survey of the dredging area.

8.2.4 Selection of Sampling Sites and Number of Samples

The method of dredging, the volume of sediment to be removed, and the horizontal and vertical heterogeneity of the sediment are key to determining station locations and the number of samples to be collected for the total dredging operation and for each project segment. When appropriate to testing objectives, samples may be composited prior to analysis (with attention to the discussion later in this Section). The appropriate number of samples and the proper use of compositing have to be determined for each operation on a case-by-case basis.

The following factors should be considered in sampling-site selection.

- Objectives of the testing program
- Accessibility
- Flows
- Mixing
- Source locations
- Available personnel and facilities
- Other physical characteristics.

The actual sampling pattern to be used is, by necessity, dependent on the site because major point sources, land-use activities, hydrologic conditions, and sample variability fluctuate from area to area.

The pattern should consider contaminant sources in each project segment and currents that could be critical to the pattern of sediment distribution. Station locations within the dredging area should include areas downstream from major point sources and in quiescent areas, such as turning basins, side channels, and inside channel bends, where fine-grained sediments are most likely to settle. Project segments selected on the basis of suspected high contamination cannot be considered as representative of the contaminant distribution in the entire dredging area. Therefore, project segments representing the proportion of the overall dredging area expected to be less contaminated than other segments have to be sampled representatively also.

Several characteristics have been established to help to define the representativeness of a sample:

- The project segment being sampled is clearly defined.
- The sampling locations are distributed randomly within each project segment.
- More than one sample should be collected from each sampling location if sample variability is suspected.
- When sediment variability is unknown, it may be necessary to conduct a preliminary survey of the dredging area to better define the final sampling program.

Sediment composition can vary in the vertical dimension as well as in the horizontal dimension. Thus, samples should be collected over the entire depth that is to be excavated unless the sediments are known to be vertically homogenous or there are adequate data to demonstrate that the contamination does not extend throughout the depth to be excavated. The easiest task in establishing a sampling program is to locate the areas of maximum concentration that generally are found near the major sources or areas of sediment deposition. However, the results from these sampling locations may not represent the range of concentrations in the total dredging area. Therefore, additional sampling has to be conducted in any areas for which inadequate data are available.

In relation to sample representativeness, it is possible to define two populations: (1) the actual composition of the area and (2) the composition of the samples obtained from the area. Ideally, these populations would be the same. However, in practice, there often are differences due to bias in the sampling program. Many factors contribute to bias, including disproportionate intensity of sampling in different parts of the dredging area and equipment limitations (i.e., extrapolating surface grab sample results to subsurface sediments).

It may be useful to develop a sampling grid for each project segment. The horizontal dimensions of each project segment are subdivided into grid cells of equal size; these are numbered sequentially within each project segment. Cells are then randomly selected for sampling. It may be important to collect more than the minimum number of samples required, especially in areas suspected of having high or highly variable contamination. Extra samples may be collected and archived should reexamination of a particular project segment(s) be warranted.

In some cases, it may be advisable to consider varying the level of sampling effort for separate project segments. Project segments suspected of containing environmentally important contaminants should be targeted for an increased level of effort so that the boundaries and characteristics of the contamination can be identified. A weighting approach can be applied whereby project segments are ranked in increasing order of concern. The weights can be used as factors when determining the number of samples within each project segment relative to other project segments.

One of the more important tasks is to determine the number of samples that should be collected within each project segment. In general, the number of samples required is inversely proportional to the amount of known information and is proportional to the level of confidence that is desired in the results and the suspected level of contamination. No specific guidance can be provided, but several general concepts are presented: (1) the greater the number of samples collected, the better the area will be defined; (2) the means of several measurements at each station within a project segment generally are less variable than individual measurements at each station would be; (3) statistics require replication because single measurements are inadequate to describe variability; and (4) the necessary number of samples is proportional to the heterogeneity of the sediment and the statistical power desired in the tests based on the sampling.

In all cases, the goal is to obtain sufficient information to evaluate the environmental impact of a dredging operation within the constraints of the operation. Although such constraints do not justify inadequate environmental evaluation, the reality of time and funding constraints have to be recognized. Possible responses to such constraints have been discussed by Higgins (1988). If the original sampling design does not seem to fit time or funding constraints, several options are available:

- Reduce the number of replicates at each station.
  This provides a more synoptic survey of distribution patterns in the project segment, but makes statistical comparisons of individual stations less powerful. This may be the easiest approach, but is not necessarily the most desirable.

- Maintain replicates, but reduce the number of sampling stations.
  This results in less detailed definition of the project segment, but maintains the power of station-to-station comparisons.
- Reduce the number of project segments into which the project is divided, but maintain the same total number of samples.
  This also results in less detailed definition of each project segment, but maintains the power of station-to-station comparisons.
- Maintain (or even increase) the number of stations sampled, and composite multiple samples from within a project segment so that a lower number of analyses are performed per project segment.

Regardless of the final decision on project segments and the number of sample stations and replicates per project segment, stations within each segment should be randomly distributed. Expected degree of contamination will be the dominant factor in initially describing the proposed project segments. If there are likely to be important variables in potential dredged-material impact within a project segment, it may be advisable either to use a stratified random-sampling approach or to redefine project-segment boundaries. Once the data from the sampling are available, to maximize the homogeneity within segments, it may be advisable to redefine the boundaries of the project segments to be used in the actual dredging.

In decisions regarding compositing of samples, the objective of obtaining an accurate representation and definition of the dredging area has to be satisfied. Compositing provides a way to analyze sediments from more stations at the same cost or from the same number of stations at lower cost. However, compositing results in a less detailed description of the area sampled than would individual analysis of each station. If, for example, five analyses can be performed to characterize a project segment, the increased coverage afforded by collecting 15 individual samples and combining sets of three into five composite samples for analysis may justify the increased time and cost of collecting the extra 10 samples. Compositing can provide the large sample volumes required for some biological tests. Composite samples represent the socalled "average" of the characteristics of the individual samples making up the composite, and can closely represent the overall characteristics of the entire volume of the material to be dredged.

When a sediment sample is collected in the field, a decision has to be made as to whether the entire sediment volume is to be considered as the sample or whether the sediment volume represents separate samples (i.e., based on observed stratification, the top 2-3 ft of a core might be considered to be a separate sample from the remainder of the core). After the sediment to be considered as a sample is identified, it has to be thoroughly homogenized. Core samples should be split before compositing. One half of the original sediment is archived should

later analysis of the individual sample be required; the other half is combined with parts of other samples. These are thoroughly homogenized, producing the composite sample.

8.2.5 Sample-Collection Methods

Sample collection requires an experienced crew, an adequate vessel equipped with precise navigational equipment and winches, and noncontaminating sampling apparatus capable of obtaining relatively undisturbed and representative samples. The major sampling effort for a proposed dredging operation is oriented toward the collection of sediment samples for physical and chemical characterization or for biological tests. Collection of water samples might also be required to evaluate potential water-column impact. Collection of organisms near the disposal site might be necessary if there is a need to characterize indigenous populations at these locations or to assess concentrations of contaminants in tissues. Organisms for use in biological-effects and bioaccumulation tests may also be field-collected.

Guidance is provided in this Section regarding the selection and use of some equipment associated with sediment, water, or organism sampling. In general, a hierarchy for sample collection should be established to prevent contamination from the previous sample, especially when using the same sampling apparatus to collect samples for different analyses. At a station where water and sediment are to be collected, water samples should be collected prior to sediment samples. The vessel should be positioned downwind or downcurrent of the sampling device. When lowering sampling devices, care should be taken to avoid visible surface slicks. The deck and sample-handling area should be kept clean to help to reduce the possibility of contamination.

EPA (1987) provides useful sampling guidance from a quality-assurance viewpoint; this document may be followed on all points that are not in conflict with the guidance in this manual. Higgins and Lee (1987) provide perspective on sediment collection and analysis as commonly practiced in USACE Districts.

8.2.5.1 Sediment-Sample Collection

Sediment samples should be collected to the planned depth of excavation (including any "overdepth" dredging), unless the sediments are known to be vertically homogenous or the deepest sediments to be excavated are known to be uncontaminated. Care should be taken to avoid contamination of sediment samples during collection and handling. Samples designated

for trace-metal analysis should not come into contact with metal surfaces, and samples designated for organic analysis should not come into contact with plastic surfaces. Samples for biological tests may be stored in clean polypropylene containers. Subsamples for particular groups of analytes may be removed from areas of the sample not in physical contact with the collecting instrument.

A coring device is recommended whenever sampling to depth is required. The choice of corer design depends upon the objectives of the sampling program, the sediment type, water depth, sediment depth, and currents. A gravity corer may be limited to cores of 1-2 m in depth, depending upon sediment grain size, degree of sediment compactness, and velocity of the drop. For penetration greater than 2 m, a vibratory corer or a piston corer may be preferable. The length of core that can be collected generally is limited to 10 core diameters in sand substrate and 20 core diameters in clay substrate. Longer cores can be obtained, but substantial sample disturbance results from internal friction between the sample and the core liner.

Freefall cores can cause compaction of the vertical structure of sediment samples. Therefore, if the vertical stratification in a core sample is of interest, a piston corer should be used. These devices utilize both gravity and hydrostatic pressure. As the cutting edge penetrates the sediments, an internal piston remains at the level of the sediment/water interface, preventing sediment compression and overcoming internal friction. If the samples will not be sectioned prior to analysis, compaction is not a problem, and freefall noncontaminating corers are a suitable alternative.

Corers are the samplers of preference in most cases because of the variation in contamination with depth that can occur in sediment deposits. Substantial variation with depth is unlikely in areas that have frequent ship traffic and from which sediments are dredged at short intervals. In these situations, accumulating sediments are resuspended and mixed semicontinuously by ship scour and turbulence, effectively preventing stratification. In such cases, grab samples can be representative of the mixed-sediment column, and corers should be necessary only if excavation of infrequently disturbed sediments below the mixed layer is planned.

Grab samplers are acceptable for collecting samples of reference or control sediments. A grab can be Teflon®-coated to prevent potential contamination of trace-metal samples. The sampling device should be rinsed with clean water between samples.

8.2.5.2 Water-Sample Collection

If water samples are necessary, they should be collected with a noncontaminating pump or, if only a small volume of water is required, with a discrete collection bottle. When sampling with a pump, the potential for contamination can be minimized by using a peristaltic or a magnetically coupled impeller-design pump. The system should be flushed with the equivalent of 10 times the volume of the collection tubing. Also, any components within several meters of the sample intake should be noncontaminating (i.e., sheathed in polypropylene or be epoxy-coated). Concern must be exercised to limit potential sample contamination from research vessels and other apparatuses used in sampling.

A discrete water sampler should be of the close/open/close type so that only the target water sample comes into contact with internal sampler surfaces. Seals should be Teflon-coated whenever possible. Water-sampling devices should be acid-rinsed prior to use for collection of trace-metal samples and rinsed with hexane (or other appropriate solvent) prior to collection of samples for organic analyses.

8.2.5.3 Organism Collection

If collection of epibenthic macrofauna is necessary, they may be collected with a trawl. Infaunal organisms may be collected with a benthic grab or a box corer. If organisms are to be maintained alive, they should be transferred immediately to containers with clean, well-oxygenated flowing seawater. Care should be taken to prevent organisms from coming into contact with potentially contaminated areas or fuels, oils, brass, copper, lead, galvanized metal, cast iron, or natural rubber.

8.2.6 Sample Handling, Preservation, and Storage

Detailed procedures for sampling handling, preservation, and storage should be part of the standard operating procedures (SOP) and protocols developed for each sampling operation. As samples are subject to chemical, biological, and physical changes as soon as they are collected, and unadulterated samples are necessary for an accurate evaluation of the dredged material. Sample handling, preservation, and storage techniques have to be designed to minimize any changes in composition of the sample by retarding chemical and/or biological activity and by avoiding contamination. Information regarding collection, volume requirements,

container specifications, preservation techniques, and storage conditions for sediment, water, and tissue samples is discussed below and summarized in Table 8-2. Additionally, EPA (1987) provides useful guidance on sampling quality assurance/quality control (QA/QC).

8.2.6.1 Sample Handling

Sufficient sample volume must be collected to

- Perform the necessary analyses
- Partition the samples for respective storage requirements (e.g., freezing for trace-metal analysis, refrigeration for bioassays)
- Archive portions of the sample for possible later analysis.

Sample handling is specific for each project and analyses to be conducted. Generally, samples to be analyzed for trace-metals should not come into contact with metals, and samples to be analyzed for organic compounds should not come into contact with plastics. All sample containers should be appropriately cleaned (acid-rinsed for analysis of metals; solvent-rinsed for analysis of organic compounds).

Samples should completely fill the storage container, leaving no airspace. If the sample is to be frozen, just enough air space should be allowed for expansion to take place. Container labels have to withstand soaking, drying, and freezing without becoming detached or illegible. The labeling system should be tested prior to use in the field.

Sediment samples for biological testing should have all living organisms removed from the sediment prior to testing. This can be best accomplished by press-sieving the sediments through a 1-mm-mesh screen. Other matter retained on the screen with the organisms, such as shell fragments, gravel, and debris, should be recorded and discarded. Prior to use in bioassays, all sediments should be thoroughly homogenized.

8.2.6.2 Sample Preservation

Because the first few hours are the most critical to changes in the sample, preservation steps should be taken immediately upon sediment collection. There is no universal preservation or storage technique. A technique for one group of analyses may interfere with other analyses. This problem can be overcome by collecting sufficient sample volume to utilize specific preservation or storage techniques for specific analytes or tests. Preservation, whether by refrigeration, freezing, or addition of chemicals, should be accomplished onboard the collecting

Table 8-2. Summary of Recommended Procedures for Sample Collection, Preservation, and Storage[a] *(continued)*

Analysis or Test	Collection Method	Amount Required	Container	Preservation Technique	Storage Conditions	Storage Duration[b]
WATER AND ELUTRIATE						
Particulate analysis	Discrete sampler or pump	500-2000 mL	Plastic or glass	Lugols solution & refrigerate	4°C	Undetermined
Metals	Discrete sampler or pump	1 L	Acid-rinsed polyethylene or glass jar[g]	pH <2 with HNO_3[g]	4°C ± 2°C[g]	Hg - 2 weeks Others - 6 months[h]
Total Kjeldahl nitrogen (TKN)	Discrete sampler or pump	100-200 mL	Plastic or glass[h]	H_2SO_4 to pH <2; refrigerate[h]	4°C[h]	24 h[h]
Chemical oxygen demand (COD)	Discrete sampler or pump	200 L	Plastic or glass[h]	H_2SO_4 to pH <2; refrigerate[h]	4°C[h]	7 days[h]
Total organic carbon (TOC)	Discrete sampler or pump	100 mL	Plastic or glass[h]	H_2SO_4 to pH <2; refrigerate[h]	4°C[h]	<48 h[h]
Total inorganic carbon (TIC)	Discrete sampler or pump	100 mL	Plastic or glass[h]	Airtight seal; refrigerate[h]	4°C[h]	6 months[h]
Phenolics	Discrete sampler or pump	1 L	Glass[h]	0.1-1.0 g $CuSO_4$; H_3PO_4 to pH <4; refrigerate[h]	4°C[h]	24 h[h]
Soluble reactive phosphates	Discrete sampler or pump	–	Plastic or glass[h]	Filter; refrigerate[h]	4°C[h]	24 h[h]
Organics	Discrete sampler or pump	4 L	Amber glass bottle[g]	Airtight seal; refrigerate	4° ± 2°C[g]	5 days[g]
Volatile organics	Discrete sampler or pump	80 mL	Glass vial[g]	HCL preservation in airtight completely filled container[g]	4° ± 2°C[g]	5 days[g]
Total phosphorus	Discrete sampler or pump	–	Plastic or glass[e]	Refrigerate	4°C[h]	7 days[h]
Total solids	Discrete sampler or pump	200 mL	Plastic or glass[h]	Refrigerate	4°C[h]	7 days[h]

(continued)

Table 8-2. Summary of Recommended Procedures for Sample Collection, Preservation, and Storage[a]

Analysis or Test	Collection Method	Amount Required	Container	Preservation Technique	Storage Conditions	Storage Duration[b]
SEDIMENT						
Chemical/Physical Analysis						
Bulk metals	Grab/corer	200 mL	Precleaned pre-weighed poly-styrene jar[c]	Dry ice[c]	$\lesssim -20°C$[c]	Hg - 30 days Others - 6 months[d]
Bulk organics [PCBs, pesticides, high molecular weight (HMW) hydrocarbons]	Grab/corer	475 mL	Solvent-rinsed glass jar with Teflon lid[c]	Dry ice[c]	$\lesssim -20°C$[c]/dark[d]	10 days[d]
Particle size	Grab/corer	75 mL	Whirl-pac bag[c]	Refrigerate	4°C	Undetermined
TOC	Grab/corer	3 L	Heat treated glass vial with Teflon-lined lid[c]	Dry ice[c]	$\lesssim -20°C$[c]	Undetermined
Sediment from which elutriate is prepared	Grab/corer	Depends on tests being performed	Glass with Teflon-lined lid	Completely fill & refrigerate	4°C/dark/airtight	Undetermined
Biological Tests						
Dredged material	Grab/corer	12-15 L per sample	Plastic bag or container[e]	Completely fill & refrigerate; sieve	4°C/dark/airtight	2 weeks[f]
Reference sediment	Grab/corer	45-50 L per test	Plastic bag or container[e]	Completely fill & refrigerate; sieve	4°C/dark/airtight	2 weeks[f]
Control sediment	Grab/corer	21-25 L per test	Plastic bag or container[e]	Completely fill & refrigerate; sieve	4°C/dark/airtight	2 weeks[f]

(continued)

Table 8-2. Summary of Recommended Procedures for Sample Collection, Preservation, and Storage[a] *(continued)*

Analysis or Test	Collection Method	Amount Required	Container	Preservation Technique	Storage Conditions	Storage Duration[b]
WATER AND ELUTRIATE *(continued)*						
Volatile solids	Discrete sampler or pump	200 mL	Plastic or glass[h]	Refrigerate	4°C[h]	7 days[h]
Sulfides	Discrete sampler or pump	–	Plastic or glass[h]	2 mL ZnOAc[h]	Ambient[h]	24 h[h]
TISSUE						
Trace metals	Trawl/Teflon-coated grab	30 g	Double Ziploc[c]	Handle w/nonmetallic forceps; plastic gloves; dry ice[c]	≲ –20°C[c]	Hg - 28 days Others - 6 months[i]
PCBs and chlorinated pesticides	Trawl/Teflon-coated grab	100 g	Hexane-rinsed double aluminum foil and double Ziploc[c]	Handle w/hexane-rinsed stainless steel forceps; dry ice[c]	≲ –20°C[c]	10 days[i]
Volatile organics	Trawl/Teflon-coated grab	50 g	Heat-cleaned aluminum foil and watertight plastic bag[i]	Covered ice chest[d]	–20°C[i]	10 days[i]
PAHs	Trawl/Teflon-coated grab	50 g	Hexane-rinsed double aluminum foil and double Ziploc[c]	Handle w/hexane-rinsed stainless steel forceps; dry ice[c]	≲20°C[c]	10 days[i]
Lipids	Trawl/Teflon-coated grab	50 g	Hexane-rinsed aluminum foil	Handle w/hexane-rinsed stainless steel forceps; quick freeze	20°C	Undetermined

[a] This table contains only a summary of collection, preservation, and storage procedures for samples. The cited references should be consulted for a more detailed description of these procedures.
[b] These are holding times for sediment, water, and tissue. References should be consulted if holding times for sample extracts are desired.
[c] NOAA (1989)
[d] Tetra Tech (1986a)
[e] Prolypropylene should be used if phalate bioaccumulation is of concern.
[f] Two weeks is recommended; up to 6 weeks is acceptable.
[g] EPA (1988)
[h] Plumb (1981)
[i] Tetra Tech (1986b)

vessel whenever possible. If final preservation techniques cannot be implemented in the field, the sample should be temporarily preserved in a manner that retains the integrity of the sample. Onboard refrigeration is easily accomplished with coolers and ice; however, samples should be segregated from melting ice or cooling water. Samples that are to be frozen on board may simply be placed in a cooler with dry ice. Sediment samples for biological analysis should be preserved at 4°C, never frozen or dried.

Additional guidance on sample preservation is given in Table 8-1.

8.2.6.3 Sample Storage

The elapsed time between sample collection and analysis should be as short as possible. The sample storage duration for chemical evaluations is specific to the chemical analyses to be conducted (Table 8-1). For biological testing, the samples *should* be tested within 2 weeks of collection, but the samples may be stored up to 6 weeks, if necessary. With passing time, moderately contaminated sediment in storage tends to become increasingly toxic to the test organisms. The longer the samples are stored, the more difficult it is to accurately determine LPC compliance.

8.2.7 Logistical Considerations and Safety Precautions

A number of frustrations in sample collection and handling can be minimized by carefully thinking through the process and requirements before going to the field. Well trained and experienced field crews should be used. Backup equipment and sampling gear and appropriate repair parts are advisable. A surplus of sampling containers and field data sheets should be available. Sufficient ice and adequate ice-chest capacity should be provided, and the necessity of replenishing ice before reaching the laboratory should be considered. A vessel with adequate deck space is safer and allows more efficient work than an overcrowded vessel. Unforeseeable circumstances are to be expected in field sampling, and time to adequately deal with the unforeseen has to be included in sampling schedules. Appropriate safety precautions have to be observed during field sampling activities.

Samples have to be properly disposed when no longer needed. Ordinary sample-disposal methods are usually acceptable, and special precautions are seldom appropriate. According to the Characterization and Assessment Division of the EPA Office of Solid Waste and Emergency Response, under 40 CFR 261.4(d)(1) even the most contaminated samples, if

collected for the sole purpose of testing, are not subject to requirements of the Federal hazardous-waste management regulations. In addition, under 40 CFR 261.5(a), if the waste generated is less than 100 kg per month, the generator is conditionally exempt as a small-quantity generator and may accumulate up to 1000 kg of waste on the property without being subject to the requirements of Federal hazardous-waste regulations. When samples have to be shipped, 49 CFR 100-177 should be consulted for current Department of Transportation regulations on packing and shipping.

8.2.8 Quality Control

Although Section 14 is devoted to QA/QC practices, it is appropriate at this point to discuss QA/QC issues specific to the collection and preservation of samples. An effective quality-control program has to be an integral part of a dredging evaluation from initiation of field collections. Potential for sample deterioration and/or contamination occurs during sample collection, handling, preservation, and storage. Approved protocols and standard operating procedures should be followed, and experienced personnel should be responsible for maintaining the integrity and identity of the samples from collection through laboratory analysis. EPA (1987) should be consulted for additional guidance generally appropriate to dredged material.

The following areas should receive special attention relative to quality control.

8.2.8.1 Documentation

A complete record of all field procedures should be maintained, including station locations, sampling methods, sample handling, preservation, and storage procedures. Dates and times of collection, preservation, and storage should be recorded. A sample-inventory log and a sample-tracking log should be maintained. Any circumstances potentially affecting sampling procedures should be documented.

8.2.8.2 Standard Operating Procedures

Written SOPs should be available for routine procedures performed during field collections. Personnel should be thoroughly familiar with these procedures before sampling is initiated.

8.2.8.3 Sample Labels

At a minimum, the following information should be included on a sample label.

- Unique identifying code
- Location (station number) and depth
- Analysis or test to be performed
- Preservation and/or storage method
- Date/time of collection
- Special remarks if appropriate
- Initials of person collecting the sample.

8.2.8.4 Sample Tracking

A procedure for tracking samples from collection through completion of analysis and sample disposal has to be in place. This procedure should incorporate a system for monitoring the condition of the sample during transport and storage. Appropriate personnel should be assigned responsibility for sample tracking and sample custody.

8.2.8.5 Archived Samples

A sample storage bank containing replicates or subsamples of analyzed samples or extra unanalyzed samples may be beneficial, especially if anomalous results are found from analyzed samples or if additional information or analyses are needed to better define sediment characteristics. Archived samples should be properly stored and inventoried.

8.3 REFERENCES

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9.0 PHYSICAL ANALYSIS OF SEDIMENT AND CHEMICAL ANALYSIS OF SEDIMENT, WATER, AND TISSUE SAMPLES

This Section provides guidance on the selection of chemical and physical parameters to aid in evaluating the acceptability of dredged material for proposed ocean disposal, and on the methods used to analyze these parameters.

The methods cited in this Section may be used to develop the required chemical information. However, other methods may provide similar results, and the final choice of analytical procedures depends upon the needs of each evaluation. In all cases, state-of-the-art methods should be used.

Any dredged material from estuarine or marine areas contains salt. The salt can interfere with the results obtained from some analytical methods. *Any methods proposed for the determination of parameters in sediment and water from estuarine or marine environments have to explicitly address steps taken to control salt interference.*

9.1 PHYSICAL ANALYSIS OF SEDIMENT

Ocean-dumping evaluations require that the physical characteristics of the dredged material be determined and used to help to assess the impact of dumping on the benthic environment and the water column. The physical analysis of sediment samples is the first step in the overall process of sediment characterization. Physical analysis provides general information on the physical characteristics of the dredged material and it can be used to assess the behavior of these sediments after disposal. These data are valuable also in helping to identify appropriate control and reference sediments for biological tests. In addition, the physical parameters can be helpful in evaluating the chemical measurements that are made as a later step in the characterization process.

The general analyses that are recommended are (1) grain size, (2) total solids/specific gravity.

Grain-size analysis is a measure of the frequency distribution of the size ranges of the particles that make up the sediment (Plumb, 1981; Folk, 1980). The general size classes of gravel, sand, silt, and clay are the most useful in describing the size distribution of particles in dredged-material samples.

Total solids is a gravimetric determination of the organic and inorganic material remaining in a sample after it has been dried at a specific temperature. The total-solids values generally are used to convert concentrations of the chemical parameters from a wet-weight to a dry-weight basis. The specific gravity of a sample is the ratio of the mass of a given volume of material to an equal volume of distilled water at the same temperature (Plumb, 1981). Because the specific-gravity analysis requires a dry sample, it is performed usually in conjunction with the total-solids determination. The specific gravity of a dredged-material sample can be used to help to predict the dispersal and settling characteristics of dredged material upon ocean disposal.

Quality-control (QC) procedures for the general characterization of sediments are necessary to ensure that the data meet acceptable criteria for precision and accuracy. At a minimum, one triplicate analysis should be performed for every 20 samples analyzed, except for TOC where all samples should be run in triplicate. In addition, one procedural blank per 20 samples should be run and the results reported for TOC analysis. Standards used for TOC determinations have to be verified by using independent check standards to verify the accuracy of the results. Quality-control limits have to be agreed upon for each analytical procedure, and have to be consistent with the overall quality-assurance (QA) plan. Standard reference materials are not available for the determination of the physical parameters in sediments; however, where possible, laboratory standards should be analyzed with the same frequency as the triplicate analyses. QA is discussed in Section 14.

9.2 DETECTION LIMITS

The selection of appropriate method detection limits (MDL) is important. MDLs should be lower than the appropriate values against which the data are to be compared for interpretation. The detection limits for an analyte should be no greater than one-third (one-half log unit) of the appropriate value for the analyte and matrix of concern. An MDL of one-fifth to one-tenth the appropriate value is desirable and sufficient in most cases. This is necessary to evaluate whether the concentration of the analyte is approaching the value critical to the decision-making process.

Further, the MDL has to be sufficiently below the appropriate value so that there is a diminished variability in numerical values in the vicinity of the appropriate value. Since no conclusion can be more certain than the least-certain measurement, excessively low MDLs will not contribute to conclusions if sampling error is the dominant variable factor. For some contaminants, such as dioxin, every effort has to be made to achieve consistent quantitation at

the lowest possible level. The detection limits have to be documented and reported for all analyses.

9.3 CHEMICAL ANALYSIS OF SEDIMENT

9.3.1 Selection of Analytical Targets (Sediment)

Chemical analysis provides information about the chemicals present in the dredged material that, if biologically available, could cause toxicity and/or be bioaccumulated. This information is valuable for exposure assessment and for deciding which of the contaminants present in the dredged material to measure in tissue samples.

If the historical review conducted in Tier I (Section 4.1) fails to produce sufficient information to develop a suitable list of potential contaminants, a list of target chemicals has to be compiled.

There are many chemicals that could be included as target analytes. Target analytes should be selected from the priority pollutant list (Table 9-1) and the information obtained from the historical review. In the context of the regulations, analysis of polynuclear aromatic hydrocarbons (PAH) in dredged material should focus on those PAH compounds that are on the priority pollutant list (Clarke and Gibson, 1987). In addition, the target list should be expanded to include other contaminants that historical information or commercial and/or agricultural applications suggest could be present at a specific dredging site -- for example, dioxins where there have been industrial fires and tributyltin near ships on which these compounds have been used.

All sediments should be analyzed for total organic carbon (TOC). The TOC content of sediment is a measure of the total amount of oxidizable organic material in a sample. The TOC method should be based on high-temperature combustion rather than on chemical oxidation. Some classes of organic compounds are not fully degraded by chemical/ultraviolet techniques. The volatile and nonvolatile organic components make up the TOC of a sample. Because inorganic carbon (e.g., carbonates and bicarbonates) can be a significant proportion of the total carbon in some sediment, the sample has to be treated with acid to remove the inorganic carbon prior to TOC analysis. The method of Plumb (1981) recommends HCl as the acid. An alternative choice might be sulfuric acid since it is nonvolatile, is used as the preservative, and does not add to the chloride burden of the sample. Whatever acid is used, it has to be demonstrated on sodium chloride blanks that there is no interference generated from the

Table 9-1. Priority Pollutants and 301(h) Pesticides Listed According to Structural Compound Class

Structural Compound Class	PP[a]	Pollutant
Phenols	65	phenol
	34	2,4-dimethylphenol
Substituted Phenols	21	2,4,6-trichlorophenol
	22	para-chloro-meta-cresol
	24	2-chlorophenol
	31	2,4-dichlorophenol
	57	2-nitrophenol
	58	4-nitrophenol
	59	2,4-dinitrophenol
	60	4,6-dinitro-o-cresol
	64	pentachlorophenol
Organonitrogen Compounds	5	benzidine
	28	3,3'-dichlorobenzidine
	35	2,4-dinitrotoluene
	36	2,6-dinitrotoluene
	37	1,2-diphenylhydrazine
	56	nitrobenzene
	61	*N*-nitrosodimethylamine
	62	*N*-nitrosodiphenylamine
	63	*N*-nitrosodipropylamine
Low Molecular Weight Polynuclear Aromatic Hydrocarbons (PAH)	1	acenaphthene
	55	naphthalene
	77	acenaphthylene
	78	anthracene
	81	phenanthrene
	80	fluorene
High Molecular Weight Polynuclear Aromatic Hydrocarbons (PAH)	39	fluoranthene
	72	benzo(*a*)anthracene
	73	benzo(*a*)pyrene
	74	benzo(*b*)fluoranthene
	75	benzo(*k*)fluoranthene
	76	chrysene
	79	benzo(*ghi*)perylene
	82	dibenzo(*a,h*)anthracene
	83	ideno(1,2,3-*cd*)pyrene
	84	pyrene
Chlorinated Aromatic Hydrocarbons	8	1,2,4-trichlorobenzene
	9	hexachlorobenzene
	20	2-chloronaphthalene
	25	1,2-dichlorobenzene
	26	1,3-dichlorobenzene
	27	1,4-dichlorobenzene
Chlorinate Aliphatic Hydrocarbons	52	hexachlorobutadiene
	12	hexachloroethane
	53	hexachlorocyclopentadiene
Halogenated Ethers	18	bis(2-chloroethyl)ether
	40	4-chlorophenyl ether
	41	4-bromophenyl ether
	42	bis(2-chloroisopropyl)ether
	43	bis(2-chlorethoxy)methane
Phthalates	66	bis(2-ethylhexy)phthalate
	67	butyl benzyl phthalate
	68	di-*n*-butyl phthalate
	69	di-*n*-octyl phthalate
	70	diethyl phthalate
	71	dimethyl phthalate
Polychlorinated Biphenyls (PCB) as Aroclors	106	PCB-1242
	107	PCB-1254
	108	PCB-1221
	109	PCB-1232
	110	PCB-1248
	111	PCB-1260
	112	PCB-1016
Miscellaneous Oxygenated Compounds	129	TCDD (dioxin)
	54	isophorone

(continued)

[a]PP: priority pollutant designation number
[b]Includes DDT, DDD, and DDE
[c]Includes α-endosulfan, β-endosulfan, and endosulfan sulfate.
[d]Chlorinated 301(h) pesticides that are not on the priority pollutant list.
[e]Organophosphorus 301(h) pesticides that are not on the priority pollutant list.

Table 9-1. Priority Pollutants and 301(h) Pesticides Listed According to Structural Compound Class *(continued)*

Structural Compound Class	PP[a]	Pollutant
Pesticides	89	aldrin
	90	dieldrin
	91	chlordane
	92	DDT[b]
	95	endosulfan[c]
	98	endrin
	99	endrin aldehyde
	100	heptachlor
	101	heptachlor epoxide
	102	α-hexachlorocyclohexane
	103	β-hexachlorocyclohexane
	104	δ-hexachlorocyclohexane
	105	γ-hexachlorocyclohexane
	113	toxaphene
	–	mirex[d]
	–	methoxychlor[d]
	–	parathion[e]
	–	malathion[e]
	–	guthion[e]
	–	demeton[e]
Volatile Halogenated Alkanes	6	tetrachloromethane
	10	1,2-dichloroethane
	11	1,1,1-trichloroethane
	13	1,1-dichloroethane
	14	1,1,2-trichloroethane
	15	1,1,2,2-tetrachloroethane
	16	chloroethane
	23	chloroform
	32	1,2-dichloropropane
	44	dichloromethane
	45	chloromethane
	46	bromomethane
	47	bromoform
	48	dichlorobromoethane
	49	fluorotrichloromethane (removed)
	50	dichlorodifluoromethane (removed)
	51	chlorodibromomethane
Volatile Halogenated Alkenes	29	1,1-dichlorethylene
	30	1,2-*trans*-dichlorethylene
	33	*trans*-1,3-dichloropropene
	33	*cis*-1,3-dichloropropene
	85	tetrachlorethene
	87	trichlorethene
	88	vinyl chloride
Volatile Aromatic Hydrocarbons	4	benzene
	38	ethylbenzene
	86	toluene
Volatile Chlorinated Aromatic Hydrocarbons	7	chlorobenzene
Volatile Unsaturated Carbonyl Compounds	2	acrolein
	3	acrylonitrile
Volatile Ethers	19	2-chlorethylvinylether bis(chloromethyl)ether (removed)
Metals	114	antimony
	115	arsenic
	117	beryllium
	118	cadmium
	119	chromium
	120	copper
	122	lead
	123	mercury
	124	nickel
	125	selenium
	126	silver
	127	thallium
	128	zinc
Miscellaneous	121	cyanide
	116	asbestos

[a]PP: priority pollutant designation number
[b]Includes DDT, DDD, and DDE
[c]Includes α-endosulfan, β-endosulfan, and endosulfan sulfate.
[d]Chlorinated 301(h) pesticides that are not on the priority pollutant list.
[e]Organophosphorus 301(h) pesticides that are not on the priority pollutant list.

combined action of acid and salt in the sample. The EPA Region II Laboratory at Edison, New Jersey, has also developed an acceptable method for TOC analysis. It is available from U.S. Environmental Protection Agency, Region II, Surveillance and Monitoring Branch, Woodbridge Avenue, Edison, NJ 08837.

9.3.2 Selection of Chemical Analytical Techniques (Sediments)

Once the list of target analytes for sediments has been established, the analytical methods for the analytes have to be determined. The methods will, to some degree, dictate the amount of sediment sample required for each analysis. Guidelines for the amount of sample to be collected are given in Table 9-2. These general sample sizes take into consideration the fact that more than one analysis may be required for each group of analytes. The amount of sample used in an analysis affects the detection limits attainable by a particular method.

For priority pollutants in sediments, the MDLs provided by EPA (1986a) may be used as general guidelines. These detection limits are analytical goals rather than requirements. Site- or operation-specific objectives may make lower or higher detection limits appropriate. If lower MDLs are required, the analysis may require more sensitive instrumentation, larger sample sizes, or additional cleanup/concentration steps. For most coastal sediments, suitable analytical methodology will control interferences such that required detection limits will be reached. A discussion of sediment MDL values is presented by Tetra Tech (1986a) and EPA (1986a). In any event, QC data should corroborate the detection limits reached, and any discrepancies have to be justified by the data.

The recommended method for the analysis of semivolatile and volatile priority pollutants in sediment is described by Tetra Tech (1986a). Analysis for organic compounds should always use capillary-column gas chromatography (GC) or gas chromatography/mass spectrometry (GC/MS) techniques. These methods provide analytically sound techniques that yield accurate data on the concentrations of chemicals in the sediment matrix. The analytical techniques for semivolatile organic compounds generally involve the solvent extraction of the organic constituents from the sediment matrix and subsequent analysis, after cleanup, using GC or GC/MS. The extensive cleanup is necessitated by the likelihood of (1) biological macromolecules, (2) sulfur from sediments with low or no oxygen, and (3) oil and/or grease in the sediment. The analysis of volatile organic compounds incorporates purge and trap techniques with analysis by either GC or GC/MS. If dioxin analysis is being performed, the methods of Kuehl *et al.* (1987) or Smith *et al.* (1984) should be consulted.

Table 9-2. Sediment Sample-Size Requirements for Chemical and Physical Analyses

Analytical Parameter	**Sediment Sample Size (g, wet wt) Delivered to Laboratory**
Organic compounds	250
Metals	100
Miscellaneous	50[a]
Grain size	100
Total organic carbon	50
Total solids/specific gravity	50

[a]Miscellaneous sample size should be increased if auxiliary analytes that cannot be included as part of the organic or metal analyses are added to the target list.

For many metals analyses, the concentration of salt may be much greater than the analyte of interest and cause unacceptable interferences in certain analytical techniques. In such cases, the freshwater approach of acid digestion followed by inductively coupled plasma or graphite furnace atomic absorption spectroscopy (GFAAS) needs to be coupled with appropriate techniques for controlling this interference. Further, it has to be remembered that Cr, Se, Sn, Sb, and As generally occur as cations with several possible oxidation states, whereas the elements Fe, Zn, Pb, Ni, Cd, and Cu occur as hydrated cations (also with different oxidation states possible). The Hg method shown by EPA (1986a) may be used for sediment analysis. Tributyltin may be analyzed by the method of Rice *et al.* (1987), and selenium and arsenic by the method of EPRI (1986).

The techniques for the analysis of chemical constituents have some inherent limitations for sediment samples. Interferences encountered as part of the sediment matrix, particularly in samples from heavily polluted areas, may limit the ability of a method to detect or quantify some analytes. Consequently, the most selective methods using GC/MS techniques are recommended for all nonchlorinated organic compounds because GC/MS analysis can often avoid problems due to matrix interferences. Gas chromatography/electron-capture detection (GC/ECD) methods are recommended as the primary analytical tool for all polychlorinated biphenyl (PCB) and pesticide analyses because GC/ECD analysis will result in lower detection limits. Two-column GC/ECD confirmation of all analytes is recommended. Alternatively, GC/MS using selected ion monitoring (SIM) can be used for PCB and pesticide analysis. A total extraction of metal ions is not necessary. The standard aqua regia extraction yields consistent and reproducible results. A total extraction of the metals can be achieved only by acid fluoride or flux fusion methods.

The traditional methods for the analysis of PCB quantify PCB as aroclor mixtures, which can result in errors in determining concentrations (Brown *et al.*, 1984). The mixture of PCB congeners making up the aroclors changes due to physical, chemical, and/or biological processes altering the distribution of individual congeners in the environment after release. Techniques that rely on quantification of PCB by aroclor assume that the distributions of PCB congeners found in environmental samples are identical to industrial formulations. This is not the case. In addition, aroclor determinations do not yield information on the potential biological significance of the PCBs (McFarland and Clarke, 1989). The most toxic PCB congeners lie mainly within the tetra-, penta-, and hexa-chlorobiphenyl isomer groups (McFarland *et al.*, 1986). More meaningful biological and toxicological information about PCB concentrations and more accurate analytical-chemistry data can be obtained by analyzing and quantifying PCBs as individual congeners or isomer classes (Cl_1-Cl_{10}). Total PCBs can be determined by the sum of

the individual congeners. This summation more accurately represents the PCB concentration in samples, as shown in the National Oceanic and Atmospheric Administration Mussel Watch Program (NOAA, 1989). PCB congener analytical methods are recommended for all analyses of PCB in sediments. Table 9-3 lists the congeners recommended for analysis based on environmental abundance, persistence, and biological importance (McFarland and Clarke, 1989). The preparation for analysis should follow the techniques described by Tetra Tech (1986a) or EPA (1986a), but the instrumental analysis and quantification of the PCBs should be performed by using standard capillary GC columns, on individual PCB isomers according to the methods reported by NOAA (1989) (see also Stalling, 1987; Dunn, 1984; Schwartz, 1984; Mullin, 1984). Based on quantitation of the congeners listed in Table 9-3, PCB concentrations should also be summed to give total PCBs in the sample according to the NOAA (1989) methods.

As stated earlier, the list of target analytes should include compounds that background and historical information suggest may be present. To further ensure that toxic compounds not included in the priority pollutant list are not overlooked in the chemical characterization of the dredged material, the analytical results should also be scrutinized by trained personnel for additional analytes that are not on the target list. The presence of persistent major socalled unknown analytes on gas chromatograms or reconstructed ion chromatograms should be noted. In such a case, methods involving GC/MS techniques for organic compounds are recommended for the identification of unknown chemicals.

9.3.3 Quality Control

Although Section 14 presents general QC/QA considerations, the EPA methods for the analysis of priority pollutants include detailed QC procedures and requirements that are appropriate for discussion here. These guidelines should be followed rigorously throughout the chemical analysis. General QC procedures should include the analysis of a procedural blank and a matrix spike along with every 10 - 20 samples processed. To measure analytical precision, one sample should be analyzed in triplicate for every 10 - 20 samples analyzed. The standard deviation and coefficient of variation should be reported. In addition, recoveries of surrogate spikes should be documented and all analytical instruments calibrated at least daily. All calibration data should be submitted to the laboratory QA officer for review.

Standard reference materials (SRM), if available, should also be routinely analyzed to determine analytical accuracy. SRMs may be obtained from the organizations listed in

Table 9-3. Polychlorinated Biphenyl (PCB) Congeners Recommended for Quantitation as Potential Contaminants of Concern

PCB Congener[a]	Congener Number[b]		
	Summation[c]	Highest Priority[d]	Second Priority[e]
a2,4' diCB	8		
2,2',5 triCB	18		18
2,4,4' triCB	28		
3,4,4' triCB			37
2,2',3,5' tetraCB	44		44
2,2',4,5' tetraCB			99
2,2',5,5' tetraCB	52		52
2,3',4,4' tetraCB	66		
2,3',4',5 tetraCB			70
2,4,4',5 tetraCB			74
3,3',4,4' tetraCB	77	77	
3,4,4',5 tetraCB			81
2,2',3,4,5' pentaCB		87	
2,2',3,4',5 pentaCB		49	
2,2',4,5,5' pentaCB	101	101	
2,3,3',4,4' pentaCB	105	105	
2,3,4,4',5 pentaCB			114
2,3',4,4',5 pentaCB	118	118	
2,3',4,4',6 pentaCB			119
2',3,4,4',5 pentaCB			123
3,3',4,4',5 pentaCB	126	126	
2',3,3',4,4' hexaCB	128	128	
2,2',3,4,4',5' hexaCB	138	138	
2,2',3,5,5',6 hexaCB			151
2,2',4,4',5,5' hexaCB	153	153	
2,3,3',4,4',5 hexaCB		156	
2,3,3',4,4',5 hexaCB			157
2,3,3',4,4',6 hexaCB			
1582,3',4,4',5,5' hexaCB			167
2,3',4,4',5',6 hexaCB			168
3,3',4,4',5,5' hexaCB	169	169	
2,2',3,3',4,4',5 heptaCB	170	170	
2,2',3,4,4',5,5' heptaCB	180	180	
2,2',3,4,4',5',6 heptaCB		183	
2,2',3,4,4',6,6' heptaCB		184	
2,2',3,4',5,5',6 heptaCB	187		187
2,3,3',4,4',5,5' heptaCB			189

(continued)

Table 9-3. Polychlorinated Biphenyl (PCB) Congeners Recommended for Quantitation as Potential Contaminants of Concern *(continued)*

PCB Congener[a]	Congener Number[b]		
	Summation[c]	Highest Priority[d]	Second Priority[e]
2,2',3,3',4,4',5,6 octaCB	195		
2,2',3,3',4,5,5',6' octaCB			201
2,2',3,3',4,4',5,5',6 nonaCB	206		
2,2',3,3',4,4',5,5',6,6' decaCB	209		

[a]PCB congeners recommended for quantitation, from dichlorobiphenyl (diCB) through decachlorobiphenyl (decaCB).

[b]Congeners are identified by their International Union of Pure and Applied Chemistry (IUPAC) number, as referenced in Ballschmiter and Zell (1980) and Mullen *et al.* (1984).

[c]These congeners are summed to determine total PCB concentration following the approach in NOAA (1989).

[d]PCB congeners having highest priority for potential environmental importance based on potential for toxicity, frequency of occurrence in environmental samples, and relative abundance in animal tissues (McFarland and Clarke, 1989).

[e]PCB congeners having second priority for potential environmental importance based on potential for toxicity, frequency of occurrence in environmental samples, and relative abundance in animal tissues (McFarland and Clarke, 1989).

Table 9-4. Sources of Marine Reference Materials and Standards

Inorganic Constituents

U.S. Department of Commerce
National Institute for Standards and Technology
Office of Standard Reference Materials
Room B3111 Chemistry Building
Gaithersburg, MD 20899
Telephone: (301) 975-6776

Marine Analytical Chemistry Standards Program
National Research Council of Canada
Division of Chemistry
Montreal Road
Ottawa, Ontario, Canada K1A0R9
Telephone: (613) 993-2359

Organic Constituents

U.S. Department of Commerce
National Institute for Standards and Technology
Office of Standard Reference Materials
Room B3111 Chemistry Building
Gaithersburg, MD 20899
Telephone: (301) 975-6776

Marine Analytical Chemistry Standards Program
National Research Council of Canada
Atlantic Research Laboratory
1411 Oxford Street
Halifax, Nova Scotia, Canada B3H3Z1
Telephone: (902) 426-8280

Table 9-4. One SRM sample should be analyzed with every batch of 10 - 20 samples. Some samples of SRMs for organic analytes include National Research Council of Canada (NRC) marine sediment HS-1 and HS-2 for PCB; NRC marine sediment HS-3, HS-4, HS-5, and HS-6 for PAH; and National Institute for Standards and Technology (NIST) SRM #1647 and SRM #1597 for PAH. SRMs for metals analysis include NBS estuarine sediment (SRM #1646); NRC marine sediments MESS-1, BCSS-1, and PACS-1; and International Atomic Energy Agency (IAEA) marine sediment SD-N-1/2(TM). Since new SRMs are appearing constantly, current listings of appropriate agencies should be consulted frequently. The QA program has to document the ability of the selected methods to cope with the high salt content of sediments.

9.4 CHEMICAL ANALYSIS OF WATER

9.4.1 Recommended Analytical Targets (Water)

Analysis of seawater to determine the potential release of dissolved chemical constituents from the dredged material (standard elutriate) may be necessary to determine compliance with the regulations. Elutriate tests (Section 10.1.2.1) involve mixing dredged material with dredging-site water and allowing the mixture to settle. The portion of the dredged material that is considered to have the potential to impact the water column is the supernatant remaining after undisturbed settling. Chemical analysis of the elutriate allows a direct comparison of the data, after allowance for initial mixing, to applicable marine water-quality criteria (WQC). When collecting samples for elutriate testing, consideration should be given to the large volumes of water and sediment required to prepare triplicate samples for analysis. In some instances, when there is poor settling, the elutriate preparation has to be performed successively several times to accumulate enough water for testing.

In selecting target analytes for water analysis, historical water-quality information from the dredging site should be evaluated along with data obtained from the chemical analysis of sediment samples. The data from the chemical evaluation of the dredged material provide a known list of constituents that might affect the water column. All target analytes identified in the sediment chemical analysis should initially be considered potential targets for water analysis. Nonpriority-pollutant chemical components that are found in measurable concentrations in the sediments should be included as targets for the water analysis if review of the literature indicates that these analytes have the potential to bioaccumulate in animals [i.e., have a high K_{ow} or bioconcentration factor (BCF)] and are of toxicological concern.

9.4.2 Selection of Analytical Techniques (Water)

In contrast to freshwater, there are generally not EPA-approved methods for analysis of saline water. Application of the freshwater methods to seawater will frequently result in much higher MDLs than are common for freshwater unless care is taken to control the effects of salt on the analytical signal. It is therefore extremely important to ascertain a laboratory's ability to execute methods and attain acceptable MDLs in matrices containing up to 3% sodium chloride.

Once the list of target analytes for water is established, the methods for analysis should be selected. The water volume delivered to the laboratory for specific analytical methods may vary. A minimum of 1 L of elutriate should be delivered to the laboratory for metals analysis (as little as 100 mL may be analyzed). One liter of elutriate should be analyzed for organic compounds. For water samples from the dredging or disposal sites, 10-L water samples should be analyzed for organic analytes and 1-L water samples should be delivered for metals analysis. Additional water samples might be required for any supplemental target compounds that cannot be determined as part of the analyses for metal or organic priority pollutants. The size of the sample is one of the limiting factors in determining the detection limits for the water analyses. In some cases, the 10-L seawater volume for organic analysis will provide MDLs below the applicable marine WQC. MDLs for these water analyses should be established on the assumption that the seawater MDLs should be lower than the WQC concentrations. Laboratories participating in this program should routinely report MDLs achieved for a given analyte.

Many of the methods cited below for priority pollutants correspond to the methods established by EPA for freshwater analysis. Modifications or substitute methods (e.g., additional extract concentration steps, larger sample sizes, or concentration of extracts to smaller volumes) might be necessary to properly determine analyte concentration in seawater or to meet the desired MDLs.

Detailed methods for the analysis of organic and inorganic priority pollutants in water are referenced in the *Federal Register* (1984, Vol. 49, No. 209) and in Methods for the Chemical Analysis of Water and Wastes (EPA, 1982). Additional approved methods can be found in U.S. EPA Contract Laboratory Program -- Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration (EPA, 1986b); Standard Methods for the Analysis of Water and Waste Water (APHA, 1989); Annual Book of Standards. Part 31, Water (ASTM, 1980); and Bioaccumulation Monitoring Guidance: 1. Estimating the Potential for Bioaccumulation of Priority Pollutants and 301(h) Pesticides Discharged into Marine and Estuarine Waters (Tetra Tech, 1985). Most of these methods will require modification to achieve low MDLs in seawater. Analysis of the

semivolatile organic priority pollutants involves a solvent extraction of water with an optional sample cleanup procedure and analysis using GC or GC/MS (Tetra Tech, 1986). The volatile priority pollutants are determined by using purge and trap techniques and are analyzed by either GC or GC/MS. If dioxin analysis is necessary, methods of Mehrle *et al.* (1988) should be consulted.

Other methods available for metals are: cadmium, copper, lead, iron, zinc, silver (Danielson *et al.*, 1978); arsenic (EPRI, 1986); selenium and antimony (Sturgeon *et al.*, 1985); very low levels of mercury (Bloom *et al.*, 1983); and tributyltin (Rice 1987).

A primary requirement of the analysis of seawater for inorganic and organic priority pollutants is to obtain detection limits that will result in usable, quantitative data that can subsequently be compared against applicable marine WQC to determine compliance with the limiting permissible concentration (LPC). Many existing EPA methods for freshwater analysis need to be adapted to achieve environmentally meaningful detection limits in seawater. Particularly of concern are procedural blanks and matrix interferences caused by the salt in seawater. Some modifications to the analytical methods for organic compounds might be required to sufficiently lower the MDLs. For example, it is recommended that sample extracts be concentrated to the lowest possible volume prior to instrumental analysis, and that instrumental injection volumes be increased to lower the limits of detection for the analytical methods used. All PCB and pesticide analytes should be analyzed by using GC/ECD, since the GC/ECD methods are more sensitive to these compounds and will lower the detection limits. PCB should be quantified as specific congeners (Mullin *et al.*, 1984; Stalling *et al.*, 1987) and as total PCBs based on the summation of particular congeners. Methods for specific PCB congener analysis are available from NOAA (1989). The congener method is accurate, provides lower detection limits, and is less subject to matrix interferences based on the selection of the individual PCB congeners used to quantify PCB.

The analysis of metals in seawater is subject to matrix interferences from sea salts, particularly sodium and chloride ions, when the samples are concentrated prior to instrumental analysis. The presence of salts in seawater samples might require the use of alternate analytical approaches to the EPA-approved freshwater methods to achieve the desired MDLs. The gold-amalgamation method with cold-vapor atomic absorption spectrophotometry (AAS) analysis is recommended to eliminate seawater matrix interferences for mercury analysis. Methods using solvent extraction and AAS analysis might be required to reduce seawater matrix interferences for the analysis of other target metals. Graphite-furnace AAS techniques after extraction are recommended for the analysis of metals, with the exception of mercury. Appropriate techniques should be used on the instruments to reduce salt interferences.

9.4.3 Quality Control

Section 14 presents a general discussion of appropriate QA/QC practices. The methods recommended for the analysis of priority pollutants in water include detailed QC procedures and requirements. These guidelines should be followed closely throughout the chemical analyses. Minimum QC procedures should include the analysis of a procedural blank and a matrix spike along with every 10 - 20 samples processed. Triplicate analysis of one sample and analysis of appropriate SRMs should be conducted with the same frequency as the blanks and matrix spikes. SRMs for organic priority pollutants are not currently available for seawater, but reference materials for inorganic compounds may be obtained from the organizations listed in Table 9-4. Seawater matrix spikes of target analytes (e.g., seawater spiked with NIST SRM 1647 for PAH) should be used to fulfill analytical accuracy requirements. Some available SRMs for priority pollutant metals in seawater are NRC seawater CASS-1 and NRC seawater NASS-2.

Since many MDL goals might be well below what current freshwater methods are able to do, it is necessary that an appropriate part of the QA program require laboratories to establish their own MDLs and provide data to support their detection limits. It is also incumbent on participating laboratories to show that modifications made to existing methods are adequately precise, accurate, and free of salt interference from seawater.

9.5 CHEMICAL ANALYSIS OF TISSUES

9.5.1 Recommended Analytical Targets (Biota)

Bioaccumulation is evaluated by analyzing the tissue of the test organisms for contaminants that are selected from the list of target analytes as being of contaminants of concern for a specific dredged material. Sediment-chemistry data and available information on the bioaccumulation potential of those analytes has to be interpreted to establish which compounds are contaminants of concern in the tissues of biota.

The *n*-octanol/water partition coefficient (K_{ow}) has traditionally been used to estimate the BCFs of many chemicals, including the priority pollutants, in organism/water systems (Chiou *et al.*, 1977; Kenaga and Goring, 1980; Veith *et al.*, 1980; Mackay, 1982).

When identifying organic contaminants of concern for bioaccumulation, a useful rule of thumb is that the potential for bioaccumulation increases as K_{ow} increases. This general relationship is often true for compounds with log K_{ow} less than approximately 6. Above this

value, there is less of a tendency for bioaccumulation potential to increase with increasing K_{ow}. Consequently, the relative potential for bioaccumulation of organic compounds can be estimated from the K_{ow} of the compounds. EPA (1985) recommends that compounds for which the log K_{ow} is greater than 3.5 be flagged for consideration for further evaluation of bioaccumulation potential. Based on the existing data, the organic compound classes of priority pollutants with the greatest potential to bioaccumulate are PAHs, PCBs, pesticides, and some phthalate esters. Generally, the volatile organic, phenol, and organonitrogen priority pollutants are not readily bioaccumulated. Some exceptions might be the chlorinated benzenes and the chlorinated phenols. Table 9-5 indicates the relative bioaccumulation potential of organic priority pollutants based on K_{ow}. If PCBs or PAHs are identified for analysis in tissues, the guidance on selection of specific analytical target compounds in Sections 9.3.1 and 9.3.2 should be followed.

The priority pollutant metals that might tend to bioaccumulate based on available BCF data are mercury, copper, arsenic, cadmium, zinc, lead, and chromium. Table 9-6 ranks the bioaccumulation potential of the priority pollutant metals based on calculated BCFs. Dredged-material contaminants with BCFs greater than 1000 (log BCF >3) should be further evaluated for bioaccumulation potential. Tables 9-5 and 9-6 have to be used with caution because they are based on calculated bioconcentration from water. Sediment-bioaccumulation tests, in contrast, are concerned with accumulation from a complex medium via *all possible routes* of uptake. The appropriate use of the tables is to help in selecting contaminants of concern for bioaccumulation analysis by providing a general indication of the relative potential for various chemicals to accumulate in tissues.

The strategy for selecting contaminants of concern for the chemical analysis of tissue of organisms should include three criteria: (1) The target analyte is present at levels of potential concern in the sediment as determined by sediment chemical analyses. (2) The target analyte has a high potential to accumulate and persist in tissues. (3) The target analyte is of toxicological concern.

Analytes that might have a lower potential to bioaccumulate, but which are present at very high concentrations in the sediments, should also be included in the target list because the bioavailability of the compound might increase as organisms encounter high levels in sediments. In addition, compounds of a high accumulation potential and of high toxicological concern should be considered, even if present at low concentrations in the sediment.

Nonpriority-pollutant chemical components that are found in measurable concentrations in the sediments should be included as targets for the tissue analysis if review of the literature indicates that these analytes have the potential to bioaccumulate in animals (i.e., have a high K_{ow} or BCF) and persist in animal tissues, and are of toxicological concern.

Table 9-5. Octanol/Water Partition Coefficients (K_{ow}) for Organic Compound Priority Pollutants and 301(h) Pesticides[a]

Pollutant	Octanol/Water Partition Coefficients (log K_{ow})	Pollutant	Octanol/Water Partition Coefficients (log K_{ow})
Di-*n*-octyl phthalate	9.2	Acenaphthylene	4.1
Indeno(1,2,3-*cd*)pyrene	7.7	Butyl benzyl phthalate	4.0
Benzo(*ghi*)perylene	7.0	PCB-1221	4.0
PCB-1260	6.9	Hexachloroethane	3.9
Mirex[b]	6.9	Acenaphthene	3.9
Benzo(*k*)fluoranthene	6.8	α-hexachlorocyclohexane	3.8
Benzo(*b*)fluoranthene	6.6	δ-hexachlorocyclohexane	3.8
PCB-1248	6.1	β-hexachlorocyclohexane	3.8
2,3,7,8-TCDD (dioxin)	6.1	γ-hexachlorocyclohexane	3.8
Benzo(*a*)pyrene	6.0	Parathion[b]	3.8
Chlordane	6.0	Chlorobenzene	3.8
PCB-1242	6.0	2,4,6-trichlorophenol	3.7
4,4'-DDD	6.0	β-endosulfan	3.6
Dibenzo(*a,h*)anthracene	6.0	Endosulfan sulfate	3.6
PCB-1016	5.9	α-endosulfan	3.6
4,4'-DDT	5.7	Naphthalene	3.6
4,4'-DDE	5.7	Fluorotrichloromethane[c]	3.5
Benzo(a)anthracene	5.6	1,4-dichlorobenzene	3.5
Chrysene	5.6	1,3-dichlorobenzene	3.4
Endrin aldehyde	5.6	1,2-dichlorobenzene	3.4
Fluoranthene	5.5	Toxaphene	3.3
Hexachlorocyclopentadiene	5.5	Ethylbenzene	3.1
Dieldrin	5.5	*N*-nitrosodiphenylamine	3.1
Heptachlor	5.4	*P*-chloro-*m* cresol	3.1
Heptachlor epoxide	5.4	2,4-dichlorophenol	3.1
Hexachlorobenzene	5.2	3,3'-dichlorobenzene	3.0
Di-*n*-butyl phthalate	5.1	Aldrin	3.0
4-Bromophenyl phenyl ether	5.1	1,2-diphenylhydrazine	2.9
Pentachlorophenol	5.0	4-nitrophenol	2.9
4-Chlorophenyl phenyl ether	4.9	Malathion[b]	2.9
Pyrene	4.9	Tetrachloroethene	2.9
2-Chloronaphthalene	4.7	4,6-dinitro-*o*-cresol	2.8
Endrin	4.6	Tetrachloroethene	2.6
PCB-1232	4.5	Bis(2-chloroisopropyl)ether	2.6
Phenanthrene	4.5	1,1,1-trichloroethane	2.5
Fluorene	4.4	Trichloroethene	2.4
Anthracene	4.3	2,4-dimethylphenol	2.4
Methoxychlor[b]	4.3	1,1,2,2-tetrachloroethane	2.4
Hexachlorobutadiene	4.3	Bromoform	2.3
1,2,4-trichlorobenzene	4.2	1,2-dichloropropane	2.3
Bis(2-ethylhexyl)phthalate	4.2	Toluene	2.2

(continued)

Table 9-5. Octanol/Water Partition Coefficients (K_{ow}) for Organic Compound Priority Pollutants and 301(h) Pesticides *(continued)*[a]

Pollutant	Octanol/Water Partition Coefficients (log K_{ow})	Pollutant	Octanol/Water Partition Coefficients (log K_{ow})
1,1,2-trichloroethane	2.2	Dimethyl phthalate	1.6
Guthion[b]	2.2	Chloroethane	1.5
Dichlorodiflouromethane[c]	2.2	2,4-dinitrophenol	1.5
2-chlorophenol	2.2	1,1-dichloroethylene	1.5
Benzene	2.1	Phenol	1.5
Chlorodibromomethane	2.1	1,2-dichloroethane	1.4
2,4-dinitrotoluene	2.1	Diethyl phthalate	1.4
2,6-dinitrotoluene	2.0	*N*-nitrosodipropylamine	1.3
Trans-1,2-dichloropropene	2.0	Dichloromethane	1.3
Cis-1,3-dichloropropene	2.0	2-chloroethylvinylether	1.3
Demeton[b]	1.9	Bis(2-chloroethoxy)methane	1.3
Chloloform	1.9	Acrylonitrile	1.2
Dichlorobromomethane	1.9	Bis(2-chloroethyl)ether	1.1
Nitrobenzene	1.9	Bromomethane	1.0
Benzidine	1.8	Acrolein	0.9
1,1-dichloroethane	1.8	Chloromethane	0.9
2-nitrophenol	1.8	Vinyl chloride	0.6
Isophorone	1.7	*N*-nitrosodimethylamine	0.6

[a]Adapted from Tetra Tech (1985).
[b]301(h) pesticides not on the priority pollutant list.
[c]No longer on priority pollutant or 301(h) list.

TABLE 9-6. Bioconcentration Factors (BCF) of Priority Pollutants[a]

Pollutant	Log BCF[b]
Metals	
Methylmercury	4.6
Phenylmercury	4.6
Mercuric acetate	3.5
Copper	3.1
Zinc	2.8
Arsenic	2.5
Cadmium	2.5
Lead	2.2
Chromium IV	2.1
Chromium III	2.1
Mercury	2.0
Nickel	1.7
Thallium	1.2
Antimony	ND
Silver	ND
Selenium	ND
Beryllium	ND
Nonmetals	
Cyanide	ND
Asbestos	ND

[a]Adapted from Tetra Tech (1986b).
[b]ND: No data.

9.5.2 Selection of Analytical Techniques (Biota)

At present, formally approved standard methods for the analysis of priority pollutants in tissues are not available. However, several studies conducted for EPA and other agencies have developed analytical methods capable of identifying and quantifying most organic and inorganic priority pollutants in tissues. The amount of tissue required for analysis is somewhat dependent on the analytical procedure. As a general guideline, 25 g (wet weight) of tissue should be delivered to the laboratory for organic analysis and 10 g delivered for metals analysis; an additional 25 g may be necessary for supplemental analyte determinations.

The determination and recording of the moisture content of tissue samples is essential to convert data between wet-weight and dry-weight bases.

The detection limits achieved for target analytes in tissue depend on the sample size as well as the specific analytical procedure. The MDLs presented in a particular analytical method should serve as goals for priority-pollutant tissue analysis. MDLs should be determined for all analytes according to guidance in 40 CFR 136 (Appendix A). Detection limits have to be specified based on the intended use of the data and specific needs of each evaluation.

The existing methods for the analysis of priority pollutants in tissue involve two separate procedures: one for organic compounds and another for metals. The recommended methods for the analysis of semivolatile organic pollutants are described in Extractable Toxic Organic Compounds, Standard Analytical Procedures of the NOAA National Analytical Facility (NOAA, 1989). These methods are currently being used in the NOAA National Status and Trends Program. The procedure involves serial extraction of homogenized tissue samples with methylene chloride, followed by alumina and gel-permeation column cleanup procedures that remove coextracted lipids. An automated gel-permeation procedure described by Krahn *et al.* (1988) is recommended for rapid, efficient, reproducible sample cleanup. The methylene chloride extract is concentrated and analyzed for semivolatile organic pollutants using GC with capillary fused-silica columns to achieve sufficient analyte resolution.

Chlorinated hydrocarbons (e.g., PCBs and chlorinated pesticides) should be analyzed by GC/ECD. It is recommended that PCBs be quantitated as specific congeners (Mullin *et al.*, 1984; Stalling *et al.*, 1987) and not by industrial formulations (e.g., aroclors) because the levels of PCBs in tissues result from complex processes, including selective accumulation and metabolism. See the discussion of PCB in Section 9.3.2. Lower detection limits and positive identification of PCBs and pesticides can be obtained by using chemical ionization mass spectrometry if necessary.

The same tissue extract is analyzed for other semivolatile pollutants (e.g., PAHs, phthalate esters, nitrosamines, phenols, etc.) using GC/MS as described by NOAA (1989), Battelle (1985), and Tetra Tech (1986b). These GC/MS methods are similar to EPA Method 8270 for solid wastes and soils (EPA, 1986). The lowest detection limits are achieved by operating the mass spectrometer in the SIM mode. Decisions to perform analysis of nonchlorinated hydrocarbons and the interpretation of resulting data should consider that many of these analytes are readily metabolized by most fish and many marine invertebrates.

If analysis of tissue samples for volatile priority pollutants is necessary, analytical methods are cited by Tetra Tech (1986b). The lipid content of the biological material is of importance in the interpretation of bioaccumulation information. A lipid determination should be performed on all biota submitted for organic analysis, and the method of Bligh and Dyer (1959) is recommended. If other methods are used, they should be referenced to results from Bligh and Dyer's method. If dioxin analysis is being performed, methods by Mehrle *et al.* (1988), Smith *et al.* (1984), or Kuehl *et al.* (1987) should be consulted.

The analysis for priority-pollutant metals involves a nitric acid or nitric acid/perchloric acid digestion of the tissue sample and subsequent analysis of the acid extract using AAS or inductively coupled plasma (ICP) techniques. Procedures for the digestion of tissue samples for priority-pollutant metals can be found in Tetra Tech (1986b). The methods used in the NOAA Status and Trends Program (NOAA, 1989) may also be used and are recommended when very low detection levels are required. Microwave technology may be used for tissue digestion to reduce contamination and to improve recovery of metals (Nakashima *et al.*, 1988). This methodology is consistent with tissue analyses performed for the NOAA Status and Trends Program, except for the microwave heating steps. Mercury analysis requires the use of cold-vapor AAS methods. The matrix interferences encountered in analysis of metals in tissue might require case-specific techniques for overcoming interference problems. If tributyltin analysis is being performed, the methods of Rice *et al.* (1987) or Uhler *et al.* (1989) should be consulted.

9.5.3 Quality Control

Section 14 presents a general discussion of appropriate QA/QC practices for tissue analysis. A procedural blank (to measure potential contamination from laboratory procedures) and a matrix spike (to measure the recoveries of the target analytes from a sample matrix) should be performed with each 10 - 20 samples. Triplicate analysis of one sample (to measure analytical precision) and appropriate SRMs (to measure analytical accuracy) should be

performed with the same frequency as the blanks and matrix spikes. SRMs for organic priority pollutants in tissues are currently not available. The National Institute for Standards and Technology (NIST) is presently developing SRMs for organic analytes. Tissue matrix spikes of target analytes should be used to fulfill analytical accuracy requirements for organic analyses. SRMs for priority-pollutant metals include NRC dogfish liver tissue (DOLT-1), dogfish muscle tissue (DORM-1), and lobster hepatopancreas reference tissue (TORT-1); and IAEA fish flesh MA-A-2(TM) and mussel tissue MAM-2(TM). Marine reference materials and standards for inorganic constituents in tissue may be obtained from the organizations listed in Table 9-4.

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10.0 GUIDANCE FOR PERFORMING TIER II EVALUATIONS

10.1 TIER II: WATER-COLUMN EFFECTS

If a water-column limiting permissible concentration (LPC) determination cannot be made in Tier I, § 227.13 requires that the Tier II water-column evaluation be conducted to determine compliance with applicable marine water-quality criteria (WQC) (Section 5.1). "Bypassing" Tier II water-column testing is allowed only if there are no marine WQC for any of the contaminants of concern in the dredged material (Figure 3-2).

Tier II testing for WQC is a two-step process that uses one of three numerical models provided in Appendix B of this manual. The first step uses the model as a screen and assumes that all of the contaminants in the dredged material are released into the water column during the disposal process. The second step applies the same model, using the results from a chemical analysis of an elutriate prepared from the dredged material (Section 10.1.2.1).

10.1.1 Screen To Determine WQC Compliance

Step 1 of the Tier II water-column evaluation determines the need for additional testing by running the appropriate numerical model under the premise that all of the contaminants will dissolve into the water column. This is a conservative assumption and serves as a screen to reduce the evaluation effort for dredged material that will cause only minimal water-column impact. In a typical disposal operation, most contaminants remain associated with the dredged material that settles to the bottom and cause limited water-column impact during descent.

Appendix B provides guidance on which numerical computer model should be applied to particular dredged-material disposal projects and the parameters that are necessary to run the programs. Versions of the models for use on IBM-compatible microcomputers and example applications are provided on the diskettes that can be found in the pocket inside the back cover of this manual.

The diskettes contain models appropriate to instantaneous discharges, continuous discharges, and hopper dredge discharges. The appropriate model for the proposed operation under consideration has to be selected according to the guidance in Appendix B. The output of the model is used to determine if additional testing is needed.

The model need be run only for the contaminant of concern that requires the greatest dilution. If the contaminant requiring the greatest dilution is shown to meet the LPC, all of the other contaminants that require less dilution will also meet the LPC. The contaminant that would require the greatest dilution is determined by calculating the dilution that would be required to meet the applicable marine WQC. To determine the dilution *D*, the following equation is solved for each contaminant of concern.

$$D = (C_s - C_{wq}) / (C_{wq} - C_{ds})$$

where C_s = concentration of the contaminant in the dredged material expressed as micrograms per liter (μg/L). [Note that most contaminant results are usually reported in micrograms per kilogram (μg/kg) dry weight. To convert the contaminant concentration reported on a dry-weight basis to the contaminant concentration in the dredged material, the dry-weight concentration must be multiplied by the mass of dredged-material solids per liter of dredged material];

C_{wq} = applicable marine WQC in micrograms per liter (μg/L); and

C_{ds} = background concentration of the constituent at the disposal site in micrograms per liter (μg/L).

Note that if the concentration of the constituent in the dredged material (C_s) is less than the applicable marine WQC (C_{wq}), no calculation is necessary since no dilution is required to meet the criteria. Note also that, if the ambient disposal-site water concentration (C_{ds}) of a constituent is greater than the applicable WQC (C_{wq}), water quality at the disposal site violates the marine WQC regardless of the proposed disposal operation, and the criteria cannot be met by dilution.

A data-analysis routine is available in the dispersion models (Appendix B) to perform the above calculations and identify the contaminant of concern that would require the greatest dilution.

The concentration of the contaminant that would require the greatest dilution is then modeled. The key parameters derived from the dispersion model are the maximum concentration of the contaminant in the water column outside the boundary of the disposal site during the 4-h initial-mixing period or anywhere in the marine environment after the 4-h initial-mixing period. If both of these concentrations are below the applicable marine WQC, the WQC LPC is met and no additional testing is required to determine compliance with the WQC. If either of these concentrations exceeds the WQC, additional testing is necessary, as described in Section 10.1.2. The procedure described above cannot be used to evaluate water-column

impact; it can be used *only* to determine whether additional testing for potential water-column impact, as described in Section 10.1.2 and 11.1, is necessary.

10.1.2 Elutriate Analysis To Determine WQC Compliance

If the numerical mixing model applied in Section 10.1.1 shows that the WQC cannot be met if all of the contaminants in the dredged material dissolve into the water column during the disposal, an elutriate-chemical analysis must be conducted. Following an elutriate procedure with the dredged material and the subsequent chemical analysis, the model applied under Section 10.1.1 is run again – with the new data that more closely estimates true disposal conditions. This second model run predicts whether or not the contaminant of concern that requires the greatest amount of dilution will meet or exceed the LPC for WQC.

10.1.2.1 Dredged-Material Preparation (Standard Elutriate Test)

Prior to use, all labware should be thoroughly cleaned. Labware should be washed as appropriate for the analysis of the contaminants of concern. At a minimum, the labware should be washed with detergent, rinsed five times with tap water, placed in a clean 10% HCl acid bath for a minimum of 4 h, rinsed five times with tap water, and then thoroughly flushed with either distilled or deionized water.

The elutriate should be prepared by using water from the dredging site. If it is known at this time that there are no WQC for all of the contaminants of concern or that synergism is suspected, enough elutriate should be prepared for the chemical and for the water-column tests.

The elutriate is prepared by subsampling approximately 1 L of the dredged material from the well-mixed original sample. The dredged material and unfiltered water are then combined in a sediment-to-water ratio of 1:4 on a volume basis at room temperature (22° ± 2 °C). This is best accomplished by volumetric displacement. After the correct ratio is achieved, the mixture is stirred vigorously for 30 min with a magnetic stirrer. At 10-min intervals, the mixture is also stirred manually to ensure complete mixing. After the 30-min mixing period, the mixture is allowed to settle for 1 h. The supernatant is then siphoned off and centrifuged or filtered through a 0.45-μm-mesh filter to remove particulates prior to chemical analysis. If the elutriate is to be used for toxicity testing, refer to the procedures in Section 11.1.4.

10.1.2.2 Chemical Analysis

Analytical procedures for specific constituents in water are presented in Section 9.4.2.

10.1.2.3 Determination of WQC Compliance (Standard Elutriate Test)

A final LPC determination for WQC compliance is made following the second run of the appropriate numerical mixing model with the data from the chemical analysis of the elutriate. As stated in Section 10.1.1, guidance on the appropriate model to select and run for this analysis is provided in Appendix B. Copies of the models are also provided on the diskettes that can be found in the pocket inside the back cover of this manual.

Also as in Section 10.1.1, the model need be run only for the contaminant that requires the greatest dilution to make an LPC determination. This contaminant may or may not be the same as that run in the model under Section 10.1.1. Calculations must therefore be conducted for all of the contaminants detected during analysis of the elutriate to determine which one requires the greatest dilution. To determine the dilution D requirements, the following equation is solved for each contaminant of concern.

$$D = (C_e - C_{wq}) / (C_{wq} - C_{ds}) ,$$

where C_e = concentration of the dissolved contaminant in the standard elutriate in micrograms per liter (μg/L);

C_{wq} = applicable marine WQC in micrograms per liter (μg/L); and

C_{ds} = background concentration of a constituent at the disposal site in micrograms per liter (μg/L).

Note that, if the concentration (C_e) of the dissolved contaminants in the elutriate is less than the applicable marine WQC (C_{wq}), no calculation is necessary since no dilution is required to meet the criteria. Note also that, if the ambient disposal-site water concentration (C_{ds}) of a constituent is greater than the applicable WQC (C_{wq}), water quality at the disposal site violates the marine WQC and the criteria cannot be met by dilution.

A data-analysis routine is available in the dispersion models to perform the above calculations and identify the contaminant of concern requiring the greatest dilution.

The concentration of the contaminant requiring the greatest dilution is then modeled. The key parameters derived from the model are the maximum concentration of the contaminant outside the boundary of the disposal site during the 4-h initial-mixing period and the maximum concentration anywhere in the marine environment after the 4-h initial-mixing period. These

values are compared with applicable marine WQC according to the guidance in Section 5.1.2, and a final LPC determination is reached for WQC compliance.

10.2 TIER II: THEORETICAL BIOACCUMULATION POTENTIAL (TBP) OF NONPOLAR ORGANIC CHEMICALS

The TBP is an approximation of the equilibrium concentration in tissues if the dredged material in question were the only source of contaminant to the organisms. The TBP calculation in Tier II is applied as a course screen to demonstrate LPC noncompliance of sediments that contain unacceptable concentrations of bioavailable contaminants of concern. At present the TBP calculation can be performed only for nonpolar organic chemicals (such as PCBs), although methods for making the calculation with metals and polar organic compounds are under development and may be added to this manual in the future. Therefore, a particular dredged material may contain contaminants of concern for which it is inappropriate to calculate TBP (e.g., polar organic compounds, organometals, and metals), and bioaccumulation evaluations of such dredged materials will require testing in Tier III or IV, as appropriate. However, even if the dredged material contains other contaminants of concern in addition to nonpolar organic contaminants of concern, it is still useful to calculate the TBP. The TBP provides an indication of the magnitude of bioaccumulation of nonpolar organic compounds that may be encountered in Tiers III and/or IV testing. Additionally, if the TBP of the nonpolar organic compounds meets the decision guidance, the calculation may eliminate the need for further evaluation of these compounds and thereby reduce efforts in Tiers III and/or IV.

For the purposes of Tier II, nonpolar organic chemicals include all organic compounds that do not dissociate or form ions. This includes the chlorinated hydrocarbon pesticides; many other halogenated hydrocarbons; PCB, many PAHs including all the priority pollutant PAHs, dioxins, furans, etc. It does not include organic acids or salts, or organometallic complexes such as tributyltin or methyl mercury. Metals and metal compounds are not included.

The distribution in the environment of nonpolar organic chemicals is controlled largely by their solubility in various media. Therefore, in sediments they tend to occur primarily in association with organic matter (Karickhoff, 1981), and in organisms are found primarily in the body fats or lipids (Konemann and van Leeuwen, 1980; Geyer *et al.*, 1982; Mackay, 1982; Bierman, 1990). Therefore, bioaccumulation of nonpolar organic compounds from dredged material can be estimated from the organic carbon content of the material, the lipid content of

the organism, and the relative affinities of the chemical for sediment organic carbon and animal lipid content.

The calculation of the TBP assumes that various lipids in different organisms and organic carbon in different sediments are similar and have similar distributional properties. Other simplifying assumptions are that chemicals are freely exchanged between the sediments and tissues and that compounds behave conservatively. In reality, compound size and structure may influence accumulation, and portions of organic compounds present on suspended particulates may have kinetic or structural barriers to availability. Two important assumptions implicit in the TBP calculations are: (1) There is no metabolic degradation or biotransformation of the chemical. (2) The sediment-associated chemical is totally bioavailable to the organism. Calculations based on these assumptions yield an environmentally conservative TBP value for the dredged material *if* the dredged material in question is the only source of the contaminant for the organism.

It is possible to relate the concentration of a chemical in one phase of a two-phase system to the concentration in the second phase when the system is in equilibrium. In calculating the TBP, interest is focused on the equilibrium distribution of a chemical between the dredged material or reference sediment and the organism. By normalizing nonpolar organic chemical concentration data for lipid content in organisms and organic carbon in dredged material or reference sediment, it is possible to estimate the preference of a chemical for either phase. This approach is based on the work of Konemann and van Leeuwen (1980) and Karickhoff (1981). McFarland (1984) took the approach one step farther. He calculated the equilibrium concentration of nonpolar organic chemicals that the lipids of an organism could accumulate as a result of exposure to dredged material would be about 1.7 times the organic carbon-normalized concentration of the chemical in the dredged material. Concentrations are directly proportional to the lipid content of the organism and the contaminant content of the dredged material or reference sediment, and are inversely proportional to the organic carbon content of the dredged or reference material (Lake *et al.* 1987).

This means that the chemical concentration that could result in an organism's lipids [the lipid bioaccumulation potential (LBP)] would theoretically be 1.7 times the concentration of that chemical in the sediment organic carbon. Rubinstein *et al.* (1987) have shown, based on field studies, that a value of 4 for calculating LBP is appropriate, and this is the value that is used in this manual. LBP represents the potential contaminant concentration in lipid *if the sediment is the only source of that contaminant to the organism*. It is generally desirable to convert LBP to whole-body bioaccumulation potential for a particular organism of interest. This is done by

multiplying LBP by that organism's lipid content, as determined by lipid analysis or from reported data. Therefore, theoretical bioaccumulation potential (TBP) can be calculated as

$$TBP = 4\ (C_s\ /\ \%TOC)\ \%L \quad ,$$

where TBP is expressed on a whole-body wet-weight basis in the same units of concentration as C_s, and

C_s = concentration of nonpolar organic chemical in the dredged material or reference sediment (any units of concentration may be used);

%TOC = total organic carbon content of the dredged material or reference sediment expressed as a decimal fraction (i.e., 2% = 0.02); and

%L = organism lipid content expressed as a decimal fraction (i.e., 3% = 0.03) of whole-body wet weight.

This calculation is based on work by McFarland and Clarke (1987), who also developed the nomograph in Figure 10-1 by which TBP can be determined graphically. Using the nomograph, it is possible to quickly estimate the TBP for organisms of various lipid contents, provided that the contaminant concentration C_s and organic carbon content %TOC of the dredged-material or reference sediment are known. Even though the nomograph does not provide as precise an answer as the equation, it is sufficient for Tier II applications. Because the TBP does not predict expected environmental concentrations but indicates the upper range, exact evaluation is not necessary. The procedure for using the nomograph is as follows.

Step 1. Determine the lipid content of an organism of interest, either from previously reported values or from laboratory analysis, and express the lipid content as percent of whole-body wet weight rather than as a decimal fraction.

Step 2. Locate the value on the righthand vertical axis that corresponds most closely to that lipid content.

Step 3. Follow the sloped line until it intersects the dredged-material or reference-sediment concentration C_s. C_s may be expressed in any units of concentration and be selected from any of four ranges: 0.1-1.0; 1-10; 10-100; or 100-1000.

Step 4. From that point, read across to the lefthand vertical axis and select the TBP value from the appropriate sediment organic carbon column expressed as percent of sediment dry weight.

Step 5. Multiply the TBP by the factor (0.1, 1, 10, 100) corresponding to the selected C_s range. The TBP will then be in the same units of concentration as C_s.

The lipid scale and the C_s scale of the nomograph can be changed by orders of magnitude by adjusting the TBP scale in the same manner. For example, if the organism of interest is a mussel having 0.3% lipid content, one would simply follow the 3% lipid line and divide the appropriate resulting theoretical bioaccumulation value by 10. If the dredged-material

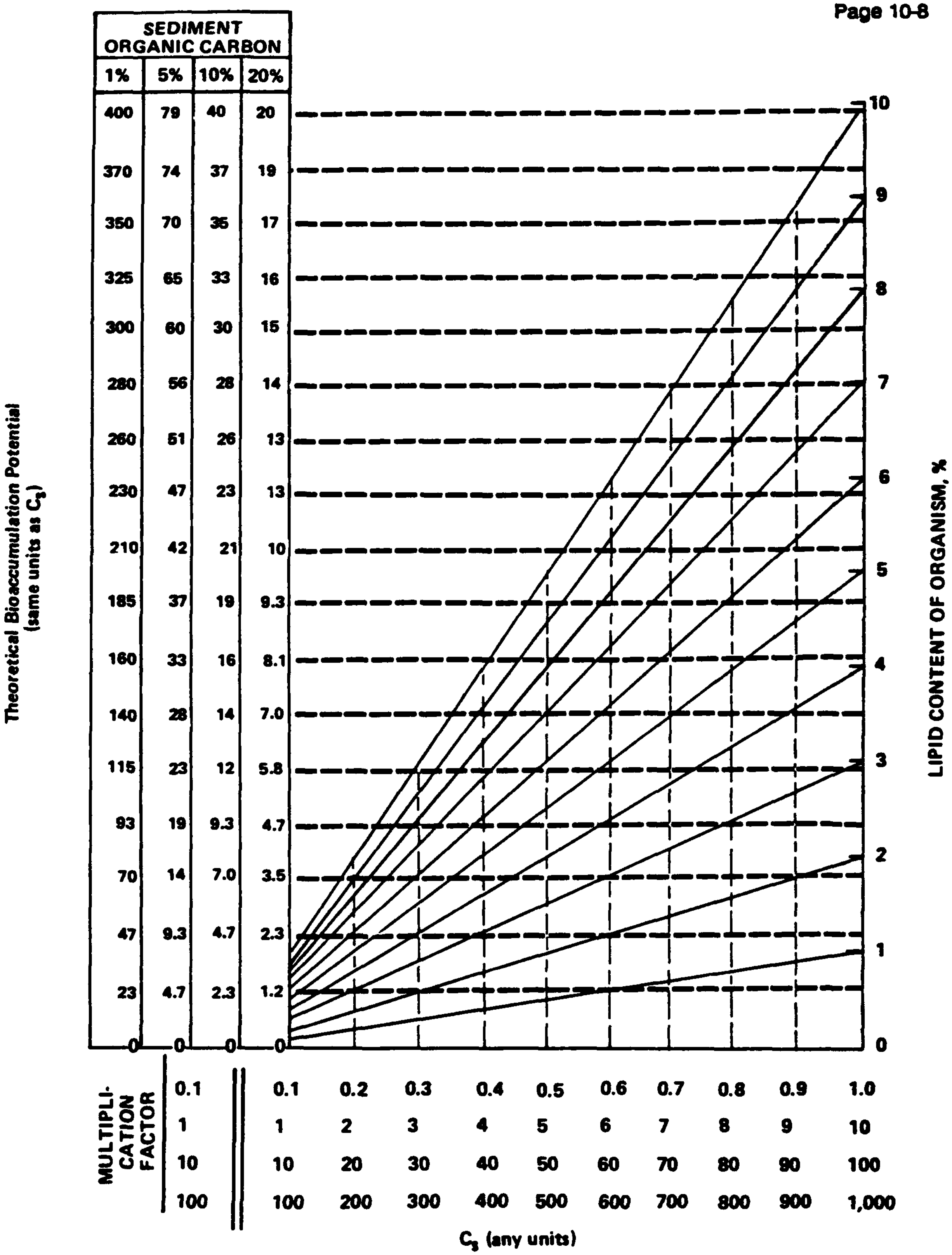

Figure 10-1. Nomograph for Determining Theoretical Bioaccumulation Potential

or reference-sediment concentration C_s of a contaminant lies above or below the C_s ranges shown on the nomograph, the units of concentration can be changed (e.g., change 0.02 parts per million to 20 parts per billion). Interpolation between lipid lines or between organic carbon columns is straightforward because all relationships are proportional. For example, for dredged material or reference sediment with an organic carbon content of 3%, the TBP would be 1/3 the TBP at 1% carbon, 5/3 the TBP at 5% organic carbon, 10/3 the TBP value at 10% organic carbon, or 20/3 the TBP at 20% organic carbon.

The following illustration of the use of the nomograph determines the TBP of total PCB by a fish of 6% lipid content exposed to a sediment containing 4 ppm PCB and 4.6% total organic carbon. Follow the 6% lipid line to a C_s value of 4 and then read across to the 5% organic carbon column to obtain a TBP of about 19 x 1 or 19 ppm. Because the organic carbon content of the sediment is actually 4.6% rather than 5%, a more precise estimate can be made by multiplying 19 by 5/4.6 to obtain a TBP of 20.6 ppm. This would be evaluated under guidance in Section 5.2 to determine whether a decision could be reached or further testing was necessary.

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11.0 GUIDANCE FOR PERFORMING BIOLOGICAL-EFFECTS TESTS

Biological-effects tests with the dredged material may be necessary if the evaluations in Tiers I and II conclude that the dredged material contains contaminants that might result in an unacceptable adverse impact to the benthic environment and/or the water column. Bioassays with whole sediment are used to determine the effects on benthic (bottom-dwelling) organisms; bioassays with suspensions/solutions of dredged material are conducted to determine the effects on water-column organisms. Bioassays should be conducted only in the tiers appropriate to provide the information necessary and sufficient for decisions.

The objective of water-column bioassays (if they are necessary) is to determine the potential impact of dissolved and suspended contaminants on organisms in the water column, after considering initial mixing period. Test organisms should be representative of sensitive water-column organisms existing in the vicinity of the disposal site.

The objective of benthic bioassays is to determine the potential impact of whole sediment on benthic organisms at and beyond the boundaries of the disposal site. The organisms used in testing should be representative of sensitive infaunal or epifaunal organisms existing in the vicinity of the disposal site. Benthic bioassays are intended to determine the potential toxicity of a dredged material as distinct from its physical effects. In tests similar to those described here, some animals are known to be affected by differences in sediment textures or absence of sediments (DeWitt *et al.*, 1988; McFarland, 1981). It is important, therefore, that test organisms and control and reference sediments be selected to minimize the artifactual effects of differences in grain size. If the sediment texture varies considerably between the dredged material and the control or reference sediments, either organisms insensitive to grain-size effects should be used or the effects of grain size have to be determined and considered when designing benthic bioassays and evaluating the test results. The purpose of the test is not to measure physical effects but to measure contaminant effects.

11.1 TIER III: WATER-COLUMN BIOASSAYS

Tests to evaluate dredged-material impact on the water column involves exposing test organisms to an elutriate dilution series containing both dissolved and suspended components of the dredged material. The test organisms are added to the exposure chambers and exposed for a prescribed period (usually 96 h). Tests with zooplankton and larvae may be run for shorter

periods. The surviving organisms are examined at specified intervals to determine if the test material is producing an effect. An introductory guide to general toxicity testing is presented in part 8000 of Standard Methods for the Analysis of Water and Waste Water (APHA, 1989). Biological-testing aspects of the Standard Methods guidelines may be followed as long as they do not conflict with the guidelines in this manual.

11.1.1 Species Selection

Paragraph 227.27(c) of the regulations defines appropriate sensitive water-column marine organism to mean at least one species each representative of phytoplankton or zooplankton, crustacean or mollusc, and fish. It is recommended that the test organisms be fish, crustaceans, and zooplankton. The test species may be from healthy laboratory cultures or may be collected from the vicinity of the disposal site or in an area of similar water quality and substrate sedimentology, but not within the influence of former or active disposal sites or other discharges. Ideally, the test species should be the same or closely related to those species that naturally dominate biological assemblages in the vicinity of the disposal site. Species characteristics to consider when designing water-column tests are

- Comply with paragraph 227.27(c)
- Are readily available year-round
- Tolerate handling and laboratory conditions
- Give consistent, reproducible response to toxicants
- Have related phylogenetically and/or by ecological requirements to species characteristic of the water column of the disposal site area in the season of the proposed disposal
- Can be readily tested as juveniles or larvae to increase sensitivity
- Are important ecologically, economically, and/or recreationally.

Note that the above test-species characteristics are not presented in order of importance, except that the first characteristic is mandatory.

With reasonable care, test organisms can be collected from wild populations and maintained in the laboratory with low mortality under controlled conditions. If the test species has not been used previously, a preliminary study should be conducted to assess the ability of the field-collected species to acclimate to laboratory conditions.

In addition to species occurring at the disposal site, other representative commercially available species or sensitive life stages of economically important species may be used. Mysids

of the genera *Mysidopsis, Neomysis,* or *Holmesimysis* are highly recommended as test species. Embryo-larval stages of crustaceans, molluscs, or fish are also appropriate sensitive marine organisms. Adult fish and molluscs and large crustaceans are not recommended for water-column testing because of their generally greater resistance to contaminants. Appropriate test species are listed in Table 11-1.

Regardless of their source, test organisms should be collected and handled as gently as possible. Field-collected animals should ŀ ⁻ansported to the laboratory in seawater of the same salinity and temperature as the water .. ɔm which they were obtained. The animals should be held in the laboratory no longer than necessary, definitely no more than 2 weeks, before they are used. During this period, they have to be gradually acclimated to the salinity and temperature at which the test will be conducted. Animals from established laboratory cultures can be held indefinitely but may also need to be gradually acclimated to the test temperature and salinity if test conditions differ from holding conditions.

11.1.2 Apparatus

Water-column bioassays generally are run as static exposures for a period of 96 h. The exposures should be conducted in glass chambers equipped with covers to minimize evaporation. The size of the chambers depends on the size of the test species. All glassware has to be extremely clean. Before use, glassware should be washed with detergent, rinsed five times with tap water, placed in a clean 10% HCl acid bath for a minimum of 4 h, rinsed five times with tap water, and then thoroughly flushed with either distilled or deionized water.

Equipment and facilities have to be available to provide acceptable lighting requirements and temperature control. An environmental incubator or a water-bath system that allows temperature control within $\pm 1°C$ is recommended. A waterproof lightbox or light table is recommended for observing zooplankton and larvae.

11.1.3 Experimental Conditions

Water-column bioassays should be conducted under conditions known to be nonstressful to the test organisms. Salinity should be stable within $+2^{o}/oo$ and temperature within $\pm 2°C$ throughout the exposure period. Dissolved-oxygen concentration should not be allowed to fall below 40% saturation. The temperature, salinity, dissolved oxygen, ammonia, and pH in the test containers should be measured and recorded daily.

Table 11-1. Examples of Appropriate Test Species for Determining Potential Water-Column Impact of Dredged-Material Disposal

Crustaceans

- Mysid shrimp, *Mysidopsis* sp.*
  Neomysis sp.*
  Holmesimysis sp.*
- Grass shrimp, *Palaemonetes* sp.
- Commercial shrimp, *Penaeus* sp.
- Oceanic shrimp, *Pandalus* sp.
- Blue crab, *Callinectes sapidus*
- Cancer crab, *Cancer* sp.

Fish

- Silversides, *Menidia* sp.*
- Shiner perch, *Cymatogaster aggregata**
- Sheepshead minnow, *Cyprinodon variegatus*
- Pinfish, *Lagodon rhomboides*
- Spot, *Leiostomus xanthurus*
- Sanddab, *Citharicthys stigmaeus*
- Grunion, *Leuresthes tenuis*
- Dolphinfish, *Coryphaena hippurus*

Zooplankton

- Copepods, *Acartia* sp.*
- Larvae of
  - Mussels, *Mytilus edulis**
  - Oysters, *Crassostrea virginica**
    Ostrea sp.*
  - Sea urchin, *Strongylocentrotus purpuratus*
    Lytechinus pictus

Bivalves

- Mussel, *Mytilus* sp.
- Oyster, *Crassostrea* sp.

Note: Examples are not presented in order of importance; however, the asterisks indicate recommended species.

11.1.4 Experimental Procedures

Elutriate Preparation

Prior to use, all glassware should be thoroughly cleaned. Glassware should be washed with detergent, rinsed five times with tap water, placed in a clean 10% HCl acid bath for a minimum of 4 h, rinsed five times with tap water, and then thoroughly flushed with either distilled or deionized water. The elutriate should be prepared using water collected from the dredging site. Disposal-site water, clean seawater, or artificial sea/salt mixtures should be used as dilution water for the tests. If sea/salt mixtures are used for preparing the dilutions, the mixtures must be prepared in strict accordance with the manufacturer's instructions and allowed to age for a minimum of 1 week (with aeration) before use in any test.

The elutriate is prepared by subsampling approximately 1 L of the homogenized dredged-material sample. The dredged material and unfiltered dredging-site water are then combined in a sediment-to-water ratio of 1:4 on a volume basis at room temperature (22° ± 2°C). This is best accomplished by volumetric displacement. After the correct ratio is achieved, the mixture is stirred vigorously for 30 min with a magnetic stirrer. At 10-min intervals, the mixture is also stirred manually to ensure complete mixing. After the 30-min mixing period, the mixture is allowed to settle for 1 h. The liquid plus the material remaining in suspension after the settling period represents the 100% liquid plus suspended particulate phase. The supernatant is then carefully siphoned off, without disturbing the settled material, and immediately used for testing. With some very fine-grained dredged materials, it may be necessary to centrifuge the supernatant until the suspension is clear enough at the first observation time for the organisms to be visible in the testing chamber.

Test Design

The number of replicate exposure chambers per treatment and the number of organisms per exposure chamber should be determined according to the guidance in Section 13.1. A minimum of five replicates per treatment and 10 organisms per replicate is recommended unless Section 13.1 indicates otherwise. In all cases, the single most important concern is that the organisms not be stressed by overcrowding.

At least three concentrations of the dredged-material elutriate should be tested; recommended treatments are 100%, 50%, and 10% of the dredged-material elutriate. Water of the type in which the animals were held prior to testing should be included as control treatments.

The toxicity of the dilution water should also be determined by conducting 100% dilution-water treatments to properly evaluate the test results.

The test organisms should be approximately of equal size and assigned randomly to the different treatments. Zooplankton and larvae are usually transferred with the aid of a pipette (Dinnel *et al.*, 1982). Care must be exercised so that air is not trapped on or under the animals during the transfer process. Larger animals may be transferred in fine-mesh nets. Animals that are dropped, physically abused, or exhibit abnormal behavior should be discarded.

The test chambers should be covered and placed in an incubator or water bath. The placement of the test containers in the incubator or water bath should be random. During the exposure period, the test medium should not be replaced, aeration should not be supplied (unless necessary to keep dissolved-oxygen concentration above 40% saturation), and the test solutions should not be stirred. Some species of crustaceans, particularly larval forms, will require feeding during the test. All food used must be analyzed to ensure that it is free of contaminants.

Recommended test duration is 48 h for zooplankton and larvae and 96 h for other organisms. For bivalve larvae, the ASTM (1988) procedure should be used. At 0, 4, 24, and 48 h (and perhaps 72 and 96 h), a lightbox or dissecting microscope is used to record the number of live animals in each chamber. Care must be exercised to minimize the stress to the animal. Only the number of living organisms are counted, not the number of dead. An animal is judged dead if it does not move either after the water is gently swirled or after a sensitive part of its body is gently touched with a probe. At each observation, a pipette or forceps is used to remove dead organisms, molted exoskeletons, and food debris.

11.1.5 Quality-Control Considerations

If mortality is greater than 10% (30% mortality/abnormality for zooplankton tests) in the control treatment or in the dilution-water treatment for a particular test species, the test should be rejected and the bioassay repeated. Unacceptably high control mortality indicates that the organisms are being affected by stresses other than contamination in the material being tested. These stresses may be due to injury or disease, unfavorable physical or chemical conditions in the test containers, improper handling or acclimation, or possibly unsuitable or contaminated water. Species selection and the potential effects of these and other variables should be carefully examined in an attempt to reduce unacceptably high mortality if the test is repeated.

Reference toxicant tests should be performed routinely on all groups of organisms used in dredged-material testing in order to determine their relative health and vigor. Many chemicals may be used satisfactorily as reference toxicants (Lee, 1980). Reference toxicant tests are performed in the absence of sediment. A geometric dilution series of five unreplicated concentrations is used. Nominal concentrations are usually sufficient for reference toxicant tests, but measured concentrations are preferred. The concentration range should be selected to give greater than 50% mortality in at least one concentration and less than 50% mortality in at least one concentration. An initial pilot test using a very wide range of concentrations may be necessary to determine the proper concentration range for reference toxicant tests. Test duration is 24 h. Ten organisms per exposure chamber are sufficient. Reference toxicant tests usually are conducted under static conditions. For each species, mortality is determined and the LC_{50} is calculated as described in Section 13.2.2.

When data for a particular reference toxicant have been generated on at least five groups of organisms of a species, two standard deviations above and below the mean are established as the bounds of acceptability. When the next group of organisms of this species is tested with this reference toxicant, if the LC_{50} is within the bounds of acceptability, the group of organisms may be used for dredged-material testing. If not, their response is atypical of the population, and that group of organisms should not be used for testing. The data from each reference toxicant test are added to the database, and the bounds of acceptability are recalculated after each test to continually improve the characterization of the typical response of the species. Reference toxicant tests should be conducted at least monthly on each species cultured inhouse, and should be performed on each lot of purchased or field-collected organisms. The basic concept and application of reference toxicant tests is discussed by Lee (1980).

General quality assurance (QA) considerations applicable to biological tests are discussed in Section 14.

11.1.6 Data Presentation and Analysis

Data Presentation

Present the data for each test species in separate tables that include the following information.

- The scientific name of the test species
- The number of animals in each treatment at the start of the test

- The number of animals alive at each observation period
- The number of animals recovered alive from each chamber at the end of the test
- Additional information such as behavioral abnormalities.

Data Analysis

It is possible that no mortality will be observed in any of the treatments or that survival in the dredged-material treatments will be equal to or higher than in the control- or in the dilution-water treatments. In either of these situations, there is no need for statistical analysis and no indication of adverse effects attributable to the dredged material. If survival in the control- or dilution-water treatments is greater than the 100% dredged-material elutriate treatment, the data have to be evaluated statistically to determine whether the dredged-material suspension is significantly more toxic than either the control or the dilution water. If greater than 50% mortality occurs in any of the elutriate treatments, it might be possible to calculate an LC_{50} value (lethal concentration to 50% of the organisms in a sample). If less than 50% mortality occurs in any of the elutriate treatments, it is not possible to calculate an LC_{50}. In such cases, the LC_{50} used in the model to determine compliance should be the 100% elutriate treatment. If the conditions are highly toxic, such that the 10% elutriate treatment has greater than 50% mortality, further dilution must be made (new treatments of less than 10% dredged-material elutriate) to attain a survival of greater than 50% and determine the LC_{50} by interpolation. Statistical procedures recommended for analyzing the test data are described in detail in Sections 13.2.1 and 13.2.2.

11.1.7 Determination of Compliance

The Tier III water-column effects evaluation involves running a numerical model to determine compliance with the LPC. A description of the models is given in Appendix B, and the models are provided on the diskettes that can be found in the pocket inside the back cover of this manual.

The diskettes contain models appropriate to instantaneous discharges, continuous discharges, and hopper-dredge discharges, as described in Appendix B. The appropriate model for the proposed operation under consideration has to be selected according to the guidance in Appendix B. Within that model, the Tier III water-column bioassay application is selected. The key parameters derived from the model for evaluating water-column toxicity in Tier III are the maximum concentration of dredged material in the water column outside the boundary of the

disposal site during the 4-h initial-mixing period, and the maximum concentration in the water column anywhere in the marine environment after the 4-h initial-mixing period.

The modeled concentrations of the dredged material (expressed as percentages) are compared to the LPC, as determined by 0.01 of the 48- or 96-h LC_{50}, depending on the test duration. Both the maximum concentration outside the disposal-site boundary during the first 4 h and the maximum concentration at any point in the marine environment after 4 h are compared to 0.01 LC_{50}. If both the modeled concentrations are less than 0.01 LC_{50}, the discharge meets the LPC. If either of the modeled concentrations exceeds 0.01 LC_{50}, the discharge does not meet the LPC.

11.2 WHOLE-SEDIMENT BIOASSAYS

Bioassays with whole sediment are designed to determine whether the dredged material is likely to produce unacceptable adverse effects on appropriate sensitive marine organisms. In acute tests, the test animals are exposed to the test sediment for 10 days and the number of survivors is recorded. For bioaccumulation tests, the concentration of contaminants is analyzed in test-organism tissue. In bioaccumulation tests, organisms are exposure to the dredged material for either 10 days or 28 days, depending on the contaminants of concern. The organisms used in both types of tests must represent the three categories of species specified in the regulations.

11.2.1 Species Selection

Appropriately sensitive benthic marine organisms are used to evaluate the potential benthic impact of dredged-material disposal. The regulations require that benthic bioassays be conducted with filter-feeding, deposit-feeding, and burrowing species [paragraph 227.27(d)]. Bioassay research on contaminated sediments (e.g., Word *et al.*, 1989; Gentile *et al.*, 1988; Rogerson *et al.*, 1985) and regulatory program experience since 1977 under the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) has shown that different species have various degrees of sensitivity to the physical and chemical composition of marine sediments.

To accurately evaluate potential benthic impact and regulatory compliance, the test species should be related as closely as possible, both phylogenetically and ecologically, to

appropriate sensitive benthic marine organisms in the disposal-site area. Commercially important benthic species in the vicinity of the disposal site may also be considered for testing.

Consideration of species sensitivity is especially important because the sediment grain size is likely to vary substantially between the dredged material, the reference sediment, and the control sediment (DeWitt *et al.*, 1988; McFarland, 1981). If candidate test species are overly sensitive to the different grain sizes (i.e., excessive mortality in the control sediments) other, more grain-size tolerant species should be considered for the project.

A list of suitable bioassay species is presented in Table 11-2. However, it is strongly recommended that the selection of bioassays species for a particular dredged-material disposal project be made in consultation with regional regulatory and scientific personnel. Minimally, two different species that together cover the three species characteristics identified in paragraph 227.27(d) should be used to evaluate a disposal project. The following is a list of characteristics to consider for species selection for dredged-material evaluations.

- Comply with paragraph 227.27(c)
- Are readily available year-round
- Ingest sediments equally well
- Tolerate grain sizes of dredged material and control and reference sediments equally well
- Give consistent, reproducible response to toxicants
- Tolerate handling and laboratory conditions
- Are related phylogenetically and/or by ecological requirements to species characteristic of the benthic environment of the disposal site in the season of the proposed disposal
- Can be readily tested as juveniles or larvae to increase sensitivity
- Are important ecologically, economically, and/or recreationally.

Note that the above characteristics are not presented in order of importance, except that the first characteristic is mandatory.

Infaunal amphipods are strongly recommended as appropriate bioassay species for acute toxicity bioassays. Infaunal amphipods are

- Sensitive to benthic impact
- Readily available
- Tolerant of a wide range of grain sizes and laboratory exposure conditions
- Ecologically relevant to most dredged-material disposal sites
- In fulfillment of the three characteristics in paragraph 227.27(d).

Table 11-2 Examples of Appropriate Test Species for Determining Potential Benthic Impact of Dredged-Material Disposal

Infaunal Amphipods

- *Ampelisca* sp.*
- *Rhepoxynius* sp.*
- *Eohaustorius* sp.*
- *Grandiderella japonica*
- *Corophium insidiosum*

Burrowing Polychaetes

- *Neanthes* sp.*
- *Nereis* sp.*
- *Nephthys* sp.
- *Glycera* sp.
- *Arenicola* sp.
- *Abarenicola* sp.

Molluscs

- Yoldia clam, *Yoldia limatula* sp.
- Littleneck clam, *Protothaca staminea*
- Japanese clam, *Tapes japonica*

Crustaceans

- Mysid shrimp, *Mysidopsis* sp.
  Neomysis sp.
  Holmesimysis sp.
- Commercial shrimp, *Penaeus* sp.
- Grass shrimp, *Palaemonetes* sp.
- Sand shrimp, *Crangon* sp.
- Ocean shrimp, *Pandalus* sp.
- Blue crab, *Callinectes sapidus*
- Cancer crab, *Cancer* sp.
- Ridge-back prawn, *Sicyonia ingentis*

Fish

- Arrow gobi, *Clevelandia ios*

Note: Examples are not presented in order of importance; however, the asterisks indicate recommended species.

Overall, infaunal amphipods are excellent bioassay organisms for short-term toxicity tests with whole sediment (Swartz *et al.*, 1979; Mearns and Word, 1982; Rogerson *et al.*, 1985; Gentile *et al.*, 1988; Word *et al.*, 1989).

Some polychaete species and juvenile forms of molluscs and crustaceans are also recommended as suitable bioassay organisms. Juvenile forms are especially useful because they are generally more sensitive than the adult forms and have direct ecological relevance. The identity of all species should be verified by experienced taxonomists, particularly for animals collected in the field. If the bioassay animals are also to be used in estimating bioaccumulation potential, the factors discussed in Section 11.1.1 for species selection should also be considered.

11.2.1.1 Infaunal Amphipods

As discussed above, infaunal amphipods are strongly recommended for conducting acute benthic bioassays. The information in Sections 11.2.1.2 through 11.2.1.5 is primarily for conducting amphipod bioassays. However, much of the information can also be used for testing other organisms.

11.2.1.2 Amphipod Handling

The number of test animals of each species in each replicate exposure chamber should be determined according to the guidance in Section 13.1. A minimum of 20 animals is recommended unless Section 13.1 indicates that fewer are sufficient. In all bioassays, the single most important concern is that the organisms not be stressed by overcrowding.

During collection, the animals should be handled as gently as possible, and placed in buckets containing about 3 cm of sediment and several liters of seawater. The animals should be transported to the laboratory in well-aerated water from the collection site. Benthic animals should be held in the laboratory in aquaria with a 5-cm layer of control sediment. This sediment should be sieved and contain no organisms that would adversely affect test results. Animals from established laboratory cultures can be held indefinitely. Animals collected from the field should be held no longer than necessary before they are used in testing. Infaunal amphipods should be held for no longer than 10 days. During the holding period, the organisms can be gradually acclimated, if necessary, to the temperature and salinity at which the toxicity test will be conducted.

11.2.1.3 Laboratory Apparatus for Amphipod Tests

The test system described by Swartz *et al.* (1985) for the phoxocephalid amphipod *Rhepoxynius abronius* is recommended for bioassays with this and other amphipod species. Some amphipods do not survive well under static conditions and, therefore, should be tested using only a continuous-flow or static-renewal test design. When static tests are not appropriate (i.e., if ammonia toxicity is suspected), a continuous-flow test system, similar to the systems described by Scott and Redmond (1989) and Word *et al.* (1989), is recommended. The American Society for Testing and Materials (ASTM Headquarters, 1916 Race St., Philadelphia, PA 19013) is preparing standardized guidance on conducting sediment bioassays with amphipods. The guidance will consist of a generic test design and species-specific appendices. When released by ASTM, this guidance for testing all species of amphipod may be followed on all points that do not conflict with this manual.

Larger aquaria (≥20 L) are recommended for larger species. Tests with large aquaria should be run under continuous-flow conditions with 90% of the water volume replaced at least once every 4 h. If a continuous-flow seawater supply is not available, the animals may be tested by using a static-renewal design. Seventy-five percent of the water in each exposure chamber should be renewed 1 h before and 48 h after test initiation and at 48-h intervals thereafter. Care should be taken to minimize resuspension of the sediments during water changes. The water should be changed more frequently if acceptable water quality cannot be maintained.

All glassware has to be extremely clean. Before use, glassware should be washed with detergent, rinsed five times with tap water, placed in a clean 10% HCl acid bath for a minimum of 4 h, rinsed five times with tap water, and then thoroughly flushed with either distilled or deionized water.

The dilution water used in both flowthrough and static renewal tests should be of a temperature, salinity, and dissolved-oxygen concentration known to be nonstressful to the test organisms, and should be stable throughout the exposure period. The seawater should be filtered (20 μm), and the flow to the exposure chamber should be directed to achieve good mixing without disturbing the sediment on the bottom of the chamber. Static-renewal tests should be conducted in a water bath or environmental chamber to maintain the temperature within $\pm 1^\circ$C of the test temperature.

The procedures for collecting sediments (and animals and water if appropriate) are described in Section 8. The sediment samples should be stored as indicated in Table 8-1. The

bioassay should include a control-sediment treatment, one or more reference-sediment treatments, and the dredged-material sample treatments.

Bioassays should be initiated as soon as practical after sediment collection, preferably within 2 weeks. However, if necessary, the sediment samples may be held up to 6 weeks before initiating bioassay tests. The number of replicate exposure chambers for the dredged material, reference, and control should be determined according to the guidance in Section 13.1. A minimum of five replicates is recommended, unless Section 13.1 indicates otherwise.

The quantity of sediment needed for the benthic tests depends on the size of the exposure chambers to be used. The test is conducted with either dredged material, reference sediment, or control sediment on the bottom of each exposure chamber. The sediment should be deep enough to meet the biological needs of the test organisms, i.e., allow organisms to burrow in their normal position, etc. In any case, it should be at least 2 cm deep.

11.2.1.4 Experimental Conditions for Amphipod Tests

Benthic bioassays should be conducted under conditions known to be nonstressful to the test organisms. Salinity should be appropriate for the geographic region and the test species and stable within $\pm 2^{o}/_{oo}$ and temperature within $\pm 2°C$ throughout the exposure period. Dissolved oxygen should be maintained above 40% saturation by gentle aeration if necessary, being careful not to resuspend the sediment. Water collected from the disposal site, clean seawater, or artificial sea-salt mixtures may be used to conduct the tests. If artificial sea-salt mixtures are used, they must be prepared in strict accordance with the manufacturer's instructions and allowed to age for at least 1 week (with aeration) before use in any tests. The standard test duration for acute toxicity bioassays on benthic organisms in Tier III is 10 days.

11.2.1.5 Experimental Procedures for Amphipod Tests

Prior to use in bioassays, all sediments must be thoroughly homogenized. Very small amounts of clean seawater may be added to facilitate mixing. If separation into liquid and solid phases occurs in posthomogenization storage, remixing will be required prior to using the sediment in the tests.

The reference and control sediments, as well as the dredged material being tested, may contain live organisms. Remove macrobenthic organisms by press-sieving the sediments through a 1-mm-mesh screen. The material remaining on the screen should be noted and

discarded. Return the sieved dredged material to its storage container and hold it at 4°C. Use the sieved sediments as soon as practical after the macroinvertebrates are removed.

The experimental procedure described in Swartz *et al.* (1985) should be followed for preparing the exposure chambers for amphipod bioassays. For larger exposure chambers, the following procedure should be used. The control sediment, reference sediment, and the dredged material should be placed in their respective aquaria deep enough to meet the needs of the test organisms, but at least 2 cm deep on the bottom of the empty exposure chambers. The sediment on the bottom of the exposure chamber and any sediment suspended during placement in the exposure chamber should be allowed to settle for 24 h before introducing the test organisms. In continuous-flow tests, the flow should be established after most of the suspended sediment has settled, usually 12 to 24 h, but at least 1 h before introducing the test organisms. Water flow and any aeration should be directed to minimize the resuspension of sediments in the exposure chambers.

The use of flowthrough exposure systems is preferred to minimize the chances that stressful artifacts of experimental procedures will affect the results; static-renewal systems may be acceptable. If static-renewal systems are used, 75% of the water in each exposure chamber should be renewed 1 h before and 48 h after test initiation and at 48-h intervals thereafter. When the water is changed, be very careful not to resuspend settled material or test organisms.

Animals that have been collected in the field and kept in holding tanks with sediment can be recaptured by gently siphoning the sediment through a 1.0-mm screen. Handle the animals as little as possible and with the utmost care. Do not use any animals that are dropped, physically abused during capture or transfer, or exhibit unusual behavior. Specific handling requirements for amphipods are described in Swartz *et al.* (1985).

Divide the test animals randomly among finger bowls, or other suitable intermediate containers, equal in number to the number of exposure chambers in the test. Randomly place 20 individuals of each species in each container with water of the same temperature and salinity and from the same source as the water being used in the test. After 30 min, remove any dead animals or animals exhibiting unusual behavior and replace them with healthy individuals. If obvious mortalities exceed 10% during this period, discontinue the test and begin a new one. Reexamine species selection, collection, and holding techniques in an effort to reduce the unacceptably high mortality in the new test.

During the exposure period, daily-observation records should be kept of obvious mortalities, emergence of infaunal organisms, formation of tubes or burrows, and any unusual behavior. Also daily records of water-quality parameters (e.g., dissolved oxygen, salinity,

temperature, pH) should be maintained. In static-renewal systems, ammonia concentrations should be measured to evaluate potential ammonia toxicity. Water-quality parameters may be kept within acceptable bounds by increasing the flow rate or frequency of water changes. Gentle aeration may also be used to keep dissolved-oxygen concentration above the 40% saturation level.

After the exposure period, the sediment in the exposure chambers is siphoned through a 0.5-mm-mesh screen. The material retained on the screen is gently rinsed with seawater and inspected for animals. Animals that show any response to gentle probing of sensitive parts should be considered alive. Specimens not recovered at the end of the test have to be considered as dead. Only living animals are counted, because dead animals may have decomposed or been eaten. If animals from the benthic bioassay are to be used in estimating bioaccumulation potential, the surviving specimens are gently and rapidly counted and then treated as described in Section 12.

11.2.2 Quality-Control Considerations

If greater than 10% mean mortality occurs in the control for a whole-sediment bioassay, the test must be repeated. Unacceptably high control mortality indicates that the organisms are being affected by important stresses other than contamination in the material being tested, and the test has to be repeated. These stresses may be due to injury or disease, unfavorable physical or chemical conditions in the test containers, improper handling or acclimation, or possibly unsuitable sediment grain size. Species selection and the potential effects of these and other variables should be carefully reexamined in an attempt to reduce unacceptably high mortality when the test is repeated.

Reference-toxicant tests should be performed routinely on all groups of organisms used in dredged-material testing. Many chemicals may be used satisfactorily as reference toxicants (Lee, 1980). Reference-toxicant tests are performed in the absence of sediment, even for animals to be used in benthic bioassays. The idea is to use short-term response to a standardized exposure as an indication of the relative health of the organisms. Sediment is unnecessary in the short reference-toxicant tests and, if used, would sorb the toxicant and invalidate the reference-toxicant test. A geometric dilution series of five unreplicated concentrations is used. Nominal concentrations usually are sufficient for reference-toxicant tests, but measured concentrations are preferred. The concentration range should be selected to give greater than 50% mortality in at least one concentration and less than 50% mortality in at least

one concentration. An initial pilot test using a very wide range of concentrations may be necessary to determine the proper concentration range for the reference-toxicant tests. Test duration is 24 h. Ten organisms per exposure chamber are sufficient. Reference-toxicant tests are usually conducted under static conditions. For each species, mortality is determined and the LC_{50} is calculated as described in Section 13.2.2.

When data for a particular reference toxicant have been generated on at least five groups of organisms of a species, two standard deviations above and below the mean are established as the bounds of acceptability. When the next group of organisms of this species is tested with this reference toxicant, if the LC_{50} is within the bounds of acceptability, the group of organisms may be used for dredged-material testing. If not, their response is atypical of the population, and that group of organisms should not be used for testing. The data from each reference-toxicant test are added to the database, and the bounds of acceptability are recalculated after each test in order to continuously improve the characterization of the typical response of the species. Reference-toxicant tests should be conducted at least monthly on each species cultured in-house, and should be performed on each lot of purchased or field-collected organisms. The basic concept and application of reference-toxicant tests is discussed by Lee (1980).

General quality-assurance (QA) guidance that is applicable to bioassays is presented in Section 14.

11.2.3 Data Analysis

Data Presentation

Present the data for each test species in separate tables that include the following information.

- The scientific name of the test species
- The number of animals in each treatment at the start of the test
- The percent of animals recovered alive from each chamber at the end of the test
- Information regarding emergence, burrowing, tube building, and behavioral abnormalities
- Water-quality data for each test chamber for each day.

Statistical Analysis

If greater than 10% mean mortality occurs in the control, the test must be repeated. It is possible that no mortality will be observed in any treatments or that the total survival in the dredged material will be equal to or higher than survival in the reference sediments. In either of these situations, there is no need for statistical analysis and no indication of adverse effects due to the dredged material. If survival in the reference sediment is higher than in the dredged-material treatments, by more than the allowable percentage for the test species (see Section 6.2), the data have to be analyzed statistically to determine whether there is a significant difference in survival between the reference material and any dredged-material sample. Statistical procedures recommended for analyzing benthic bioassay data are described in detail in Section 13.2.3.

11.2.4 Determination of Compliance

Guidance on the use of the results to reach a decision is provided in Section 6.2.

11.3 TIER IV: CHRONIC-EFFECTS EVALUATIONS

At present, there are no routine methods available for assessing the chronic effects (i.e., effects on growth or reproductive processes) of contaminated sediments on benthic marine or estuarine organisms. However, a number of laboratory tests are under development or could be approved for this purpose. When standardized chronic-effects tests are approved, they will be incorporated in Tier III.

Ideally, chronic-effects bioassays measure reproductive effects on a sensitive sediment-ingesting, infaunal animal. A number of species of polychaetes and amphipods and certain species of bivalve molluscs (e.g., *Macoma* sp., *Yoldia limatula*) can be used. The primary disadvantage of this approach is that most species of infaunal polychaetes, amphipods, and molluscs have relatively long life cycles, and a test of several months or longer would be needed to accurately assess reproductive effects. It might be possible, however, to measure effects on growth the correlate with reproductive effects within a shorter exposure period. It might also be possible to measure bioenergetic alterations that correlate with reproductive suppression without conducting a full life-cycle test, as has been demonstrated with mysids (Carr *et al.*, 1985).

11.4 TIER IV: CASE-SPECIFIC EVALUATIONS

Biological effects tests in Tier IV should be used only in situations that warrant special investigative procedures. In such cases, test procedures have to be tailored for specific situations, and general guidance cannot be offered in the context of this manual. Such studies have to be selected, designed, and evaluated as the need arises, with the assistance of administrative and scientific expertise from headquarters of EPA and the USACE, and other sources if appropriate.

In some cases, the potential for chronic benthic impact may be determined from properly designed and conducted field studies. The use of field studies for predictive purposes is valid only where there is a true historical precedent for the proposed operation being evaluated. That is, field study can be used only for maintenance dredging where the quality of the sediment to be dredged can be shown not to have deteriorated or become more contaminated since the last dredging and disposal operation. In addition, the disposal has tc be proposed for the site at which the dredged material in question has been previously disposed, or for a site with similar sediment type supporting a similar biological community. Under these conditions, field studies can provide very realistic predictions of effect because benthic animals have been exposed throughout their life cycles to the chemical, physical, and biological conditions prevailing at the disposal site. Although field assessments are frequently of limited usefulness because of the above constraints, when the constraints are met, field assessments can be valuable.

11.5 REFERENCES

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12.0 GUIDANCE FOR PERFORMING BIOACCUMULATION TESTS

Bioaccumulation refers to the accumulation of contaminants in the tissues of organisms through any route, including respiration, ingestion, or direct contact with contaminated sediment or water. The regulations require that bioaccumulation be considered as part of the environmental evaluation of dredged material proposed for ocean dumping. This consideration involves predicting whether there will be a cause-and-effect relationship between an animal's presence in the area influenced by the dredged material and an environmentally important elevation of its tissue content or body burden of contaminants above that in similar animals not influenced by the disposal of the dredged material. That is, it has to be predicted whether an animal's exposure to the influence of the dredged material is likely to cause a meaningful elevation of contaminants in its body.

Many marine organisms are capable of metabolizing some types of organic compounds to varying degrees, and the ability of each species to metabolize the specific contaminant(s) of concern influences the tissue concentration of those chemicals. Organic contaminants such as polychlorinated biphenyls (PCB) and other synthetic compounds can accumulate to high levels in animal tissues because they are highly resistant to metabolic degradation. Many polynuclear aromatic hydrocarbons (PAH), on the other hand, are readily taken up by many organisms, but might not be found in high concentrations in tissue because some of the parent compounds are rapidly metabolized. The metabolites are not easily quantified by standard analytical methods, but in many cases are potent toxicants that can adversely affect the organisms in which they occur. Relatively low concentrations of organic chemicals in tissues may thus suggest either low bioavailability and therefore low bioaccumulation, or that bioaccumulation was followed by metabolization. Therefore, it is important to evaluate PAH bioaccumulation in species that have only limited ability to metabolize them. Bivalve molluscs are generally considered to satisfy this requirement. For purposes of regulation, analyses of PAH in dredged material and organisms exposed to it should focus on the PAH on the priority pollutant list. The rationale for this recommendation is provided by Clarke and Gibson (1987).

12.1 TIER III: DETERMINATION OF BIOAVAILABILITY

Bioavailability tests are designed to evaluate the potential of benthic organisms to bioaccumulate contaminants of concern from the proposed dredged material. The *Guidance Manual: Bedded Sediment Bioaccumulation Tests*, by Lee *et al.* (1989), discusses bioaccumulation methodology in detail and may be followed on any matter that does not conflict with this manual. Tier III bioavailability tests are based on analysis of tissues of organisms after 10 or 28 days of exposure. The 10-day exposure test is appropriate when all contaminants of concern are metals, whereas 28-day exposure tests should be used when any contaminant of concern is organic or organometallic (i.e., not an element). As discussed in Section 6.3, even though concentrations of these contaminants may not be at the steady state after 10 or 28 days, these tests determine the potential for bioaccumulation and provide the information for decision-making in the Tier III bioaccumulation evaluation.

12.1.1 Species Selection and Apparatus

Bioaccumulation tests must be conducted with appropriate benthic marine organisms. Paragraph 227.27(d) of the regulations defines this to mean that filter-feeding, deposit-feeding, and burrowing species must be submitted to tests that evaluate the bioaccumulation potential of contaminants in the proposed dredged material. These categories of species are broad and overlapping. The present recommendation is that a burrowing polychaete and a deposit-feeding bivalve mollusc be tested. These two organisms satisfy the requirements specified in paragraph 227.27(d) and are relevant to evaluating contaminant bioavailability at disposal sites.

Many species can metabolize PAH, thus giving a misleading indication of bioaccumulation potential. Therefore, it is essential that bioaccumulation studies include one or more species with very low ability to metabolize PAH. Bivalve molluscs are widely accepted as meeting this requirement.

Species characteristics to consider when selecting organisms for bioaccumulation tests are as follows.

- Comply with paragraph 227.27(d)
- Readily available year-round
- Provide adequate biomass for analysis
- Ingest sediments

- Tolerate grain sizes of dredged material and control and reference sediments equally well
- Tolerate handling and laboratory conditions
- Related phylogenetically and/or by ecological requirements to species characteristic of the disposal-site area
- Important ecologically, economically, and/or recreationally
- Inefficient metabolizers of contaminants, particularly PAH

Note that the above test-species characteristics are not presented in order of importance, except that the first characteristic is mandatory.

Regional scientists and regulatory personnel can be consulted for additional guidance for bioaccumulation-species selection. Examples of appropriate species for bioaccumulation testing are presented in Table 12-1

A minimum of several grams of tissue has to be available to allow measurement of chemical concentrations (Section 9.5.2). In samples that do not contain sufficient tissue, it will be impossible to quantify the amount of contaminant present. Because data in the form of "concentration below detection limits" are not quantitative, it is vital that tissue sufficient to allow definitive measurement of concentration be collected for each species.

The apparatus to be used are those described for benthic bioassays in Section 11.2. In addition, aquaria with clean, sediment-free water are necessary to hold the organisms during the period required to void their digestive tracts. If the biological needs of the organisms require the presence of sediment, clean sand should be used.

12.1.2 Experimental Conditions

The test conditions are similar to that described in Section 11.2 for whole-sediment bioassays. Control animals should be sampled and archived at both the beginning and the end of bioaccumulation tests. If discrepancies are found during the data analysis (Section 12.1.4), the archived samples can be analyzed to obtain more information on the test conditions and possibly resolve the problems.

Animals should not be provided food or additional sediment during the test. Animals to be used to evaluate bioavailability are taken from the dredged-material samples after 10 or 28 days of exposure.

It is necessary to empty or remove the digestive tracts of the animals immediately after sampling. Sediment in the digestive tracts may contain inert constituents and the contaminants

Table 12-1 Examples of Appropriate Test Species for Determining Potential Bioaccumulation from Whole-Sediment Tests.

Polychaetes	**Molluscs**
Neanthes sp.*	Macoma clam, *Macoma* sp.*
Nereis sp.*	Yoldia clam, *Yoldia limatula*
Nephthys sp.*	Nucula clam, *Nucula* sp.
Arenicola sp.	Littleneck clam, *Protothaca staminea*
Abarenicola sp.	Japanese clam, *Tapes japonica*
Fish	Quahog, *Mercenaria mercenaria*
Arrow gobi, *Clevelandia ios*	**Crustaceans**
Topsmelt, *Atherinops affinis*	Ridge-back prawn, *Sicyonia ingentis*
	Shrimp, *Penaeus* sp.

Note: Examples are not presented in order of importance; however, the asterisks indicate recommended species.

of concern in forms that do not become biologically available during passage through the digestive tract.

If the animals are large enough to make it practical, the best procedure is to excise the digestive tracts as soon as possible after sampling. However, test organisms are seldom large enough to allow this, and most organisms have to be allowed to excrete the material. Organisms are placed in separate aquaria in clean, sediment-free water to purge their digestive tracts. Some polychaetes will pass material through the digestive tract only if more material is ingested. These animals have to be purged in aquaria with clean sand. Animals are not fed during the purging period. Fecal material is siphoned from the aquaria twice during the 24-h purging period. To minimize the possibility of loss of contaminants from the tissues, purging for longer periods is not recommended. The shells or exoskeletons of molluscs or crustaceans are removed and not included in the analysis. These structures generally contain low levels of contaminants and would contribute weight but little contaminants to the analysis. This would give an artificially low indication of bioavailability.

12.1.3 Chemical Analysis

Contaminants of concern to be assessed for bioavailability are those identified in Sections 4.2 and 9.5.1. Analytical procedures for contaminants of concern in tissue are presented in Section 9.5.2.

12.1.4 Data Analysis

The data should be presented in a table that lists the tissue concentration of each contaminant of concern measured in the organisms exposed to the dredged material and reference sediment.

To evaluate the significance of dredged-material contaminant bioaccumulation, the contaminant concentration of the test-organism tissue is statistically compared to *FDA Action Levels for Poisonous and Deleterious Substances in Fish or Shellfish for Human Food* (Table 6-1). (Refer to Figures 3-3.) Depending on the outcome of this comparison, tissue concentrations may also be statistically compared with those tissues of animals exposed to the reference material (Section 13.3.1.2). In some cases, the tissue concentration in animals exposed to one or more of the dredged-material samples may be less than or equal to that in animals exposed to the reference sediment. This in no way reflects adversely on the quality of

the evaluation, but simply gives no indication of bioaccumulation potential for the contaminant, species, and dredged-material sample in question.

The sample of animals taken at the initiation of the exposure can be useful in interpreting results. It can add perspective to the magnitude of uptake during the exposure period, and in some cases has shown that elevated body burdens were not due to the dredged material or reference sediment but were already present in the organisms at the start of the test.

12.1.5 Determination of Compliance

Guidance on the use of the results of the determination of bioavailability in relation to FDA levels and bioavailability from reference sediment to reach a decision in Tier III is presented in Section 6.3.

12.1.6 Quality-Control Considerations

Reference-toxicant tests should be performed routinely on all groups of organisms used in dredged-material bioaccumulation testing in order to determine their relative health and vigor. Many chemicals may be used satisfactorily as reference toxicants (Lee, 1980). Reference-toxicant tests are performed in the absence of sediment, even for animals to be used in benthic bioaccumulation testing. The idea is to use short-term response to a standardized exposure as an indication of the relative health of the organisms. Sediment is unnecessary in the short reference-toxicant tests and, if used, would sorb the toxicant and invalidate the reference-toxicant test. A geometric dilution series of five unreplicated concentrations is used. Nominal (rather than measured) concentrations are usually sufficient for reference-toxicant tests. The concentration range should be selected to give greater than 50% mortality in at least one concentration and less than 50% mortality in at least one concentration. An initial pilot test using a very wide range of concentrations may be necessary to determine the proper concentration range for the reference-toxicant tests. Test duration is 24 h. Ten organisms per exposure chamber are sufficient. Reference-toxicant tests are conducted usually under static conditions. For each species, mortality is determined and the LC_{50} is calculated as described in Section 13.2.2.

When data for a particular reference toxicant have been generated on at least five groups of organisms of a species, two standard deviations above and below the mean are established as the bounds of acceptability. When the next group of organisms of this species is

tested with this reference toxicant, if the LC_{50} is within the bounds of acceptability, the group of organisms may be used for dredged-material bioaccumulation testing. If not, their response is atypical of the population, and that group of organisms should not be used for testing. The data from each reference-toxicant test are added to the database and the bounds of acceptability are recalculated after each test in order to continuously improve the characterization of the typical response of the species. Reference-toxicant tests should be conducted at least monthly on each species cultured inhouse, and should be performed on each lot of purchased or field-collected organisms. The basic concept and application of reference-toxicant tests is discussed by Lee (1980).

General quality-assurance (QA) guidance applicable to bioaccumulation testing is presented in Section 14.

12.2 TIER IV: DETERMINATION OF STEADY-STATE BIOACCUMULATION

Bioaccumulation evaluation at Tier IV provides for determination, either by laboratory testing or by collection of field samples, of the steady-state concentrations of constituents in organisms exposed to the dredged material as compared with organisms exposed to the reference material. Steady-state concentrations determined in the laboratory or in the field are used in the same way to make Tier IV decisions according to the guidance in Section 7.2.

12.2.1 Laboratory Assessment of Steady-State Bioaccumulation

Tier IV laboratory bioaccumulation testing is based on the American Society for Testing and Materials (ASTM) standard practice for conducting bioconcentration tests with fishes and saltwater bivalve molluscs (ASTM, 1984). The Tier IV test is a 28-day exposure to deposited dredged material from which steady-state concentration of contaminants in organism tissues is calculated based on time-series sampling.

12.2.1.1 Species Selection and Apparatus

The necessary species and apparatus are those indicated in Section 12.1.1 for Tier III bioaccumulation testing.

12.2.1.2 Experimental Conditions

Experimental conditions are the same as those described in Section 12.1.2 for determination of bioavailability. A series of tissue samples taken during the exposure period provides the basis for determining the rate of uptake and elimination of contaminants by the organism. From these rate data, the steady-state concentration of contaminants in the tissues can be calculated, even though the steady state might not have been reached during the actual exposure. Steady state is defined for the purposes of this test as the concentration of contaminant that would occur in tissue after the organisms were exposed to the dredged or reference material for a very long time under constant exposure conditions.

At the time when the animals are placed in the aquaria to begin the exposure phase, an initial time-0 sample of each species is collected for tissue analysis. Additional tissue samples are collected from each of the five replicate reference and dredged-material aquaria at intervals of 2, 4, 7, 10, 18, and 28 days after exposure begins. Calculation of steady state as described in Section 13.3.2 requires that the data describe the inflection in the uptake curve. This might not require analysis of the samples collected at the later time intervals given above. If logistically practical, it may be cost-effective to submit the Day 2, 4, 7, and 10 samples to the laboratory for analysis and continue the experiment to collect the Day 18 and 28 samples. If the data from the first sampling times clearly include the inflection of the uptake curve, analysis of the samples from later intervals may not be necessary.

12.2.1.3 Chemical Analysis

Contaminants of concern to be assessed for bioaccumulation are those identified in Sections 4.2 and 9.5.1. Analytical procedures for contaminants of concern in tissues are presented in Section 9.5.2. As described in Section 12.1.2, sediment has to be removed from the digestive tracts of the animals before they are preserved.

12.2.1.4 Data Analysis

Complete tissue concentration data for all tissue samples should be presented in a table. Recommended statistical methods for fitting a curve to the data to determine steady-state concentration in the tissue are presented in Section 13.3.2. The statistical procedures use an iterative curve-fitting process to determine the key variables (k_1C_s the uptake rate-constant times

the contaminant concentration in the sediment, and k_2 the depuration rate constant). An initial value for C_s has to be supplied. When the sediment concentration of the contaminant of concern is used, the ratio of k_1/k_2 is the sediment bioaccumulation factor (BAF) (Lake *et al.* 1987; Rubinstein *et al.*, 1987), the ratio of steady-state tissue concentration to sediment concentration.

12.2.1.5 Determination of Compliance

Decisions are based on the magnitude of bioaccumulation from the dredged material, and its comparison with the FDA levels, steady-state bioaccumulation from the reference sediment, and the body burden of reference organisms. Guidance for making decisions in Tier IV based on these comparisons is presented in Section 7.2.

12.2.1.6 Other Considerations

Although procedures for performing bioavailability and steady-state bioaccumulation tests have been discussed separately, it may be practical to combine these procedures in practice. This can be done by following the steady-state bioaccumulation procedure, but initially analyzing only the 10- or 28-day sample. If the use of the data from this analysis as part of the Tier III bioavailability evaluation does not provide for decision-making, then the remaining time-series samples may be analyzed and used in the Tier IV steady-state bioaccumulation evaluation.

12.2.1.7 Quality-Control Considerations

Guidance on quality-control (QC) considerations for bioaccumulation testing is provided in Section 12.1.6.

12.2.2 Field Assessment of Steady-State Bioaccumulation

Field-sampling programs overcome difficulties related to quantitatively considering field-exposure conditions in the interpretation of test results, since the animals are exposed to the conditions of mixing and sediment transport actually occurring at the disposal site in question. Difficulties related to the time required to conduct laboratory bioaccumulation studies are also overcome if organisms already living at the disposal site are used in the field bioaccumulation

studies. The use of this approach for predictive purposes is technically valid only where there is a true historical precedent for the proposed operation being evaluated. That is, it can be used only in maintenance dredging where the quality of the sediment to be dredged can be shown not to have deteriorated or become more contaminated since the last dredging and disposal operation. In addition, the disposal has to be proposed for the site at which the dredged material in question has been previously disposed or for a site of similar sediment type supporting a similar biological community. Knowledge of the contaminant body burden of the organisms living around the proposed disposal site is used in evaluating bioaccumulation results in Tier IV (Section 7.2).

12.2.2.1 Apparatus

The following is a general description of the major items required for field assessment of bioaccumulation potential. Additional miscellaneous equipment will have to be furnished.

- A vessel capable of operating at the disposal site and equipped to handle benthic sampling devices. Navigation equipment has to be sufficient to allow precise positioning.
- Sampling devices such as a box corer, Smith-MacIntyre or other benthic grab. Corers are less satisfactory because they sample a smaller surface area and have a greater penetration than is needed.
- Stainless steel screens of 1-mm mesh to remove animals from the sediment.
- Tanks for transporting the animals to the laboratory in collection-site water.
- Laboratory facilities for holding the animals prior to analysis.
- Chemical and analytical facilities as required for the desired analyses.

12.2.2.2 Species Selection

The species selected for analysis have to be present in sufficient numbers for collection of an adequate sample at all stations. The same species have to be collected at all stations because bioaccumulation cannot be compared across species lines.

For each species at each station, a minimum of several grams of tissue has to be collected to allow measurement of chemical concentrations. In samples that do not contain sufficient tissue, it will be impossible to quantify the amount of contaminant present. Because data in the form of "concentration below detection limits" are not quantitative, it is vital that sufficient tissue to allow definitive measurement of concentration be collected for each species at

each station. The ability to obtain sufficient tissue is a critical factor in selecting species for use in bioaccumulation studies, and in determining the practicality of the field assessment approach.

If possible, several samples of sufficient size for analysis should be collected at each sampling station to provide a statistical estimate of variability in tissue content of the contaminants of concern. Collection of more than one sample per station, however, may prove impractical if a composite of many small organisms have to be used or if suitable organisms are not abundant at the disposal site.

To minimize the numbers and collection effort required, it is desirable to select the largest appropriate species. However, highly mobile epifauna (such as crabs, lobsters, shrimp, and fish) should not be used, because a cause-and-effect relationship cannot be established between their location when collected and their body burden at the time of collection. Therefore, relatively immobile species that are fairly large, such as bivalves, some gastropods, large polychaetes, etc., are the most desirable organisms. Any relatively immobile species collectable in sufficient numbers at all stations may be used, but the required collection effort increases sharply as organism size decreases.

As discussed at the beginning of this Section, many species can metabolize PAH, thereby giving a misleading indication of bioaccumulation potential. Therefore, it is essential that bioaccumulation studies include one or more species with very low ability to metabolize PAH. Bivalve molluscs are widely accepted as meeting this requirement.

12.2.2.3 Sampling Design and Conduct

Sufficient tissue to obtain definitive body-burden values has to be collected from each of at least three stations within the disposal-site boundaries. It is mandatory that several stations be sampled, rather than collecting all of the animals at one station. This will provide a measure of the variability that exists in tissue concentrations in the animals in the area. Samples from all stations should be collected on the same day if possible, and, in any case, within 4 days.

12.2.2.4 Basis for Evaluation of Bioaccumulation

Tier IV bioaccumulation, whether based on laboratory or field assessment, is evaluated (Section 7.2) by comparison to contaminant concentrations in field organisms living around, but not affected by, the disposal site. This is very similar to the reference-area approach (Section 3.1.2.1). To generate these data, at least three stations have to be located in an uncontaminated

material sedimentologically similar to that within the disposal site, in a direction perpendicular to the net bottom transport. Data from these sites will provide the level of contaminants in tissues to which those levels found in organisms exposed to the dredged material may be compared. If the direction of net bottom transport is not known, at least six stations surrounding the disposal site should be established in sediments sedimentologically similar to those within the disposal site.

In all cases, it is mandatory that several stations be sampled, rather than collecting all of the animals at one station. This will provide a measure of the variability that exists in tissue concentrations in the animals in the area. Samples from all stations should be collected on the same day if possible, and, in any case, within 4 days.

12.2.2.5 Sample Collection and Handling

When the collection vessel has been positioned, make repeated collections at the same spot until an adequate tissue volume is obtained. Gently wash the sediment obtained by the sampler through 1-mm-mesh stainless-steel screens, and place the retained organisms of the desired species in holding tanks. Never retain an animal that shows any indication of injury.

Label the samples clearly and return the animals to the laboratory, being careful to keep them separated and to maintain nonstressful levels of temperature and dissolved oxygen. In the laboratory, maintain the samples in clean water in separate containers. Do not place any sediment in the containers and do not feed the animals. Immediately discard any organisms that die.

It is necessary to remove sediment from the digestive tracts of the animals because it may contain inert constituents and the contaminants of concern in forms that do not become biologically available during passage through the digestive tract. If the animals are large enough to make it practical, the best procedure is to excise the digestive tracts as soon as possible after collection. However, animals are seldom large enough to allow this, and most organisms have to be allowed to excrete the material. Surviving organisms are placed in separate aquaria in clean, sediment-free water to purge their digestive tracts. Some polychaetes will pass material through the digestive tract only if more material is ingested. These animals have to be purged in aquaria with clean sand. Animals are not fed during the purging period. Siphon fecal material from the aquaria twice during the 24-h purging period. Purging for longer periods of time is not recommended to minimize the possibility of loss of contaminants from the tissues.

Also remove the shells or exoskeletons of molluscs or crustaceans. These structures generally contain low levels of contaminants and would contribute weight but few contaminants if they were included in the analysis. This would give an artificially low indication of bioaccumulation.

12.2.2.6 Chemical Analysis

The contaminants of concern to be assessed for bioaccumulation are those identified in Sections 4.2 and 9.5.1. Analytical procedures for specific constituents are presented in Section 9.5.2.

12.2.2.7 Data Analysis

Complete tissue concentration data for all samples should be presented in table format. Recommended statistical methods are presented in Section 13.3.

12.2.2.8 Determination of Compliance

Decisions are based on the magnitude of bioaccumulation in organisms collected within the boundaries of the disposal site, and its comparison with bioaccumulation in organisms living around the disposal site, but not affected by the site. Guidance for making regulatory decisions based on this comparison is presented in Section 7.2.

12.3 REFERENCES

ASTM. 1984. Standard Practice for Conducting Bioconcentration Tests with Fishes and Saltwater Bivalve Mollusks. Standard Practice No. E-1022-84. American Society for Testing and Materials, Philadelphia, PA.

Clarke, J.U., and A.B. Gibson. 1987. Regulatory identification of petroleum hydrocarbons in dredged material. Proceedings of a Workshop. Misc. Pap. D-87-3. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, D.R., 1980. Reference toxicants in quality control of aquatic bioassays. Pp. 188-199 in A.L. Burkema, Jr., and J. Cairns, Jr. (Eds.), *Aquatic Invertebrate Bioassays*. ASTM Spec. Tech. Publ. 715. American Society for Testing and Materials, Philadelphia, PA.

Lee, H., III, B.L. Boese, J. Pelliter, M. Winsor, D.T. Specht, and R.C. Randall. 1989. *Guidance Manual: Bedded Sediment Tests.* U.S. Environmental Protection Agency, Pacific Ecosystems Branch, Bioaccumulation Team, Newport, OR. EPA-600/x-89-302. ERLN-N111.

13.0 STATISTICAL METHODS

This Section presents the appropriate statistical methods for analyzing data from bioassays and bioaccumulation tests. The methodology is not intended to be exhaustive, nor is it intended to be a "cook-book" approach to data analysis. Statistical analyses are routine only under ideal experimental conditions. The methods presented here will usually be adequate for the tests conducted under the conditions specified in this document. An experienced applied statistician should be consulted whenever there are questions.

The following are examples of departures from ideal experimental conditions that may require additions to or modifications of the straightforward statistical methods presented in this chapter:

- Unequal numbers of experimental animals assigned to each treatment container, or loss of animals during the experiment
- Unequal numbers of treatment replications of the treatments (i.e., containers or aquaria)
- Measurements scheduled at selected time intervals actually performed at other times,
- Different conditions of salinity, pH, dissolved oxygen, temperature, etc., among exposure chambers
- Differences in placement conditions of the testing containers, or in the animals assigned to different treatments.

The following statistical methods will be presented as each applies to a specific test procedure.

- Sample-size determinations
- Data-scale transformations
- Variance homogeneity tests
- Two-sample *t*-tests
- Analysis of variance (ANOVA)
- Multiple comparisons among treatment means
- Confidence interval calculations

The statistical methods are illustrated in this manual with example IBM PC programs using the SAS System (SAS Institute, 1985). This manual does not constitute official endorsement or approval of these commercial hardware or software products. Other equally acceptable hardware and software products are commercially available and may be used to perform the necessary analyses. Whenever it is necessary to write original programs to perform statistical analysis, the appropriateness of the techniques and accuracy of the calculations must be very carefully verified and documented.

13.1 SAMPLE-SIZE CONSIDERATION

The goal in analyzing the bioassay and bioaccumulation test data is to determine whether the mean effect of exposure to a dredged material is significantly greater than the mean effect of exposure to a reference sediment. For both the dredged material and the reference sediment, the data consist of responses measuring the effect of the material on *k* organisms in each of *n* replicate samples. In Sections 10 and 11, where guidance for performing the various tests is provided, *k* is usually set at 10 to 20 organisms per replicate, depending on the test. In the two-sample statistical test for significance, it is necessary to determine the number of replicate measurements per treatment group *n*, which must be taken to detect differences between the groups, while also taking cost and handling time into consideration.

Two formal hypotheses underlie the statistical analysis of data in the two sample situations. Let μ_R denote the mean effect of exposure to the reference sediment R, and let μ_D denote the mean effect of exposure to the dredged material D. Then, these two hypotheses are defined as follows.

<u>Null hypothesis</u>

H_0: $\mu_D = \mu_R$.

There is no difference in mean effect between the treatment (dredged material) and reference groups of animals.

<u>Alternative hypothesis</u>

H_1: $\mu_D > \mu_R$.

The mean effect of the dredged material is greater than the mean effect of the reference sediment.

Our test of hypothesis will either reject H_0 for H_1 or will fail to reject H_0. A "one-tailed" test is used because there is little concern about identifying a lower exposure effect in dredged material than in reference sediment.

In performing the test of hypothesis and in determining the sample size to use in the test, the evaluator must be aware of the probabilities for two types of errors that can occur in the conclusion. A Type I error occurs when, after analysis of the data, H_0 is rejected when it was actually true. A Type II error occurs when H_0 is not rejected when it actually should have been rejected. The probability of a Type I error is often represented by the letter α; the probability of a Type II error is often written as β.

In the example, a Type I error occurs when it is concluded that the mean effect of the dredged material is greater than the mean effect of the reference sediment when, in fact, the true mean effect of the dredged material is no greater than that for the reference sediment. On the

other hand, a Type II error occurs when it is concluded that there is no difference in mean effects of the two materials when, in fact, the true mean effect of the dredged material is greater.

The power of a statistical test is defined as $1 - \beta$, which is the probability of rejecting H_0 when it should be rejected. In this example, the power is the probability of concluding that mean effect is greater in the dredged-material group when, in fact, this is true. The conclusions are based on performing a two-sample *t*-test. In this type of test, the power depends on the actual difference in mean effects that we wish to detect, the (pooled) standard deviation of the responses within each treatment group, and the (common) sample size within each treatment group. Under ideal circumstances, the experimenter wishes to maximize the power subject to a fixed probability α of Type I error.

More accurately, the power of a statistical test depends on δ/σ, where δ is $|\mu \quad - \mu|$ and σ is the pooled standard deviation of responses within the two treatment groups, as well as on the sample size. For a fixed sample size, large values of δ/σ lead to high power. However, if δ/σ is treated as fixed, the power can be increased by increasing the sample size. Thus, the experimenter will decide in advance what size difference in treatment means δ is necessary for the test to detect, relative to the variation σ within treatment groups, and then choose sample size n large enough to achieve a given power.

If the response is highly variable within treatment groups, only large differences in the true mean effect between dredged material and reference groups are likely to be detected. Conversely, if the response is less variable, smaller differences in true mean effect between the dredged material and reference groups can be detected. This is due to the relationship between power and the ratio δ/σ.

For a selected sample size, Table 13-1 presents the calculated power (in percent) for the one-tailed test (Cohen 1977), assuming a Type I error probability of 0.05 and $\delta/\sigma = 1$. Thus, it is assumed that the variability within treatment groups is equal to the difference in mean effects that are detected. From this table, it is seen that for a sample size of five per treatment group, the power is 0.43. This means that a difference in mean effect of one standard deviation between the dredged material and the reference sample would be detected 43% of the time. Similarly, to detect a true difference in mean effect of one standard deviation 80% of the time at $\alpha = 0.05$, the number of replicates per treatment would have to be approximately 13.

Throughout this document, a minimum of five replicate samples from the test containers is recommended for each treatment level. Experience has shown this number of replicates to be cost-effective and easy to manage. However, as shown, it is important to select a sample size large enough to achieve a high statistical power in detecting differences in the treatment groups.

Table 13-1. Power Calculations for One-Tailed Tests for Selected Sample Sizes[a] [after Cohen, 1977]

Sample Size	Power(%)[b]
30	99
25	97
20	93
15	86
10	71
9	66
8	62
7	66
6	50
5	43
4	36
3	28
2	20

[a]Where $\alpha = 0.05$ and $\delta/\sigma = 1$.
[b]Power is $(1 - \beta)100$.

13.2 BIOLOGICAL EFFECTS

13.2.1 Tier III Water-Column Bioassays

The objective of the analysis of Tier III water-column toxicity test data is to assess the evidence for reduced survival due to toxicity of suspended plus dissolved dredged-material constituents, and to calculate the median lethal concentration (LC_{50}) of the material from the serial dilution experiment described in Section 11.1.4.

At the end of the exposure period, the effects, if any, on the survival of the test organisms should be clearly manifest in the 100% concentration (undiluted) test container. When the dilutions were prepared with other than control water, the dilution-water treatment is preferred over the control water for the following statistical analysis. The appropriate statistical test for detecting a significant difference in survival between two independant samples, i.e., the dilution water and the 100% concentration, is the two-sample *t*-test (Snedecor and Cochran, 1980). The usual *t* statistic for testing the equality of means x_1 and x_2 from two independent samples with n_1 and n_2 observations is

$$t = (\bar{x}_1 - \bar{x}_2) / \sqrt{s^2 \, (1/n_1 + 1/n_2)} \quad ,$$

where s^2, the pooled variance, is calculated as

$$s^2 = \{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\} \div (n_1 + n_2 - 2) \quad ,$$

and where s_1^2 and s_2^2 are the sample variances of the two groups. This statistic is compared with the student-*t* distribution with $n_1 + n_2 - 2$ degrees of freedom.

The use of this *t* statistic depends on the assumption that the variances of the two groups are equivalent. Under the assumption of unequal variances, the *t* statistic is computed as

$$t = (\bar{x}_1 - \bar{x}_2) \; / \; \sqrt{s_1^2/n_1 + s_2^2/n_2} \quad .$$

This statistic is compared with the student-*t* distributions with degrees of freedom given by Satterthwaite's (1946) approximation:

$$df = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{(s_1^2/n_1)^2/(n_1 - 1) + (s_2^2/n_2)^2/(n_2 - 1)} \quad .$$

The assumption of equal variances can be tested by comparing the folded *F* statistic with the *F* distribution having $n_1 - 1$ and $n_2 - 1$ degrees of freedom. F' is calculated as

$$F' = (\text{larger of } s_1^2, s_2^2) \,/\, (\text{smaller of } s_1^2, s_2^2)$$

When F' is large, the hypothesis of equal variance is more likely to be rejected. This *F* test is a two-tailed *F* test since we do not specify which variance is expected to be larger.

Table 13-2 contains sample data from a 96-h water-column bioassay using a seawater control and dissolved plus suspended dredged-material constituents at four serial dilutions. In this example, mean mortality in the control is less than 10%, indicating the acceptability of the test.

Figure 13-1 illustrates an SAS/PC program that will perform a two-sample *t*-test between control and the 100% concentration, and a Levene's test of the homogeneity of sample variances. The results from this program are given in Figures 13-2 and 13-3. Figure 13-2 lists data (produced of by the PROC PRINT; statement) and the two-sample *t*-test results (produced by the statement PROC TTEST COCHRAN; and the next three statements). Three *t*-test results are given: two versions of the *t*-test for assuming unequal variances, and one for use if the variances in the two treatments are equal.

The F' statistic is used in testing the hypothesis that the sample variances of the control data and 100% concentration data are equal (Steel and Torrie, 1980). The F' test in the example in Figure 13-2 is significant at the 0.064 level, indicating that if the true variability of responses was equal between the two groups, then we expect to observe data with as much or more unequal variability as we had in this set of data only 6.4% of the time. Since this probability is so low, these data suggest that variances in the two groups are in fact not equal. The test is on the verge of being significant, if we are judging significance at the 0.05 level.

Table 13-2. Number of Survivors in a Hypothetical Water-Column Bioassay after 96 h.

Replicate[a]	Concentrations[b]				
	Control[c]	100	50	25	12.5
1	20	6	8	12	17
2	19	7	8	18	17
3	20	9	9	15	18
4	20	5	10	14	16
5	19	8	11	13	18
Totals	98	35	46	72	86

[a]20 organisms per replicate at initiation of the test.
[b]Percent concentrations of dissolved plus suspended dredged-material constituents:
[c]Control: clean seawater.
100%: 1 part suspension and 0 part seawater
50%: 1 part suspension and 1 part seawater
25%: 1 part suspension and 3 parts seawater
12.5%: 1 part suspension and 7 parts seawater

```
*****************************************************************************
*  This SAS program performs a two-sample t-test on results from  *
*  a 96-hour water column bioassay.  The t-test compares the      *
*  number of surviving organisms in the control (seawater) to the *
*  number of surviving organisms in the 100% concentration.  To   *
*  test for equality of variances between samples, the F' test    *
*  Levene's test are performed.                                   *
*****************************************************************************;
options nodate nonumber linesize=80 pagesize=60;

 /* Identify the treatment group codes */
proc format;
  value trtfmt 1='Control'
               2='100%';

 /* Input the bioassay data after the CARDS; statement, listing the */
 /* treatment group code, then the number of survivors in the group */
data susphase;
  input trtmnt num_sviv @@;
  label trtmnt='Treatment Group'
        num_sviv='# of Survivors';
  format trtmnt trtfmt.;
  CARDS;
1 20 1 19 1 20 1 20 1 19
2  6 2  7 2  9 2  5 2  8
;

proc sort data=susphase;
  by trtmnt;

 /* Print out the bioassay data */
PROC PRINT data=susphase label noobs;
  var num_sviv;
  by trtmnt;
  title 'Water Column Bioassay Data Listing';

 /* Perform the two-sample t-test to compare the average number of      */
 /* survivors between the two treatment groups.  The t-statistic will be */
 /* calculated under two scenarios:  when the sample variances are      */
 /* significantly different and when they are not.  The F' test for     */
 /* equality of variance is also performed.                             */
PROC TTEST cochran data=susphase;
  class trtmnt;
  var num_sviv;
  title 'Results of Two-Sample t-test on Water Column Bioassay Data';
```

(continued)

Figure 13-1. **Example SAS/PC Program To Perform Two-Sample *t*-Test and Levene's Homogeneity of Variance Test for a Hypothetical Water-Column Bioassay from Data in Table 13-2**

```
 /* Perform Levene's test for equality of sample variances.  This test is */
 /* is not as sensitive to departures from normality as is the F' test.   */
 /* First, calculate the treatment means */
PROC MEANS data=susphase noprint;
  var num_sviv;
  by trtmnt;
  output out=meanout mean=average;

 /* Second, calculate the deviations of responses from their means */
data sustwo;
  merge susphase meanout;
  by trtmnt;
  deviatns = abs(num_sviv - average);
  label deviatns = 'Absolute Deviation from Average'
        average = 'Group Average';
  keep trtmnt num_sviv average deviatns;

PROC PRINT data=sustwo label noobs;
  var num_sviv average deviatns;
  by trtmnt;
  format average deviatns 4.1;
  title 'Levene''s Test on Water Column Bioassay Data';

 /* Finally, perform the ANOVA on the absolute deviations to perform */
 /* Levene's test                                                    */
PROC GLM data=sustwo;
  class trtmnt;
  model deviatns=trtmnt;
run;
```

Figure 13-1. *(continued)* **Example SAS/PC Program To Perform Two-Sample *t*-Test and Levene's Homogeneity of Variance Test for a Hypothetical Water-Column Bioassay from Data in Table 13-2**

Water Column Bioassay Data Listing

------------------------- Treatment Group=Control -------------------------

of Survivors
20
19
20
20
19

------------------------- Treatment Group=100% -------------------------

of Survivors
6
7
9
5
8

Results of Two-Sample t-test on Water Column Bioassay Data

TTEST PROCEDURE

Variable: NUM_SVIV   # of Survivors

TRTMNT	N	Mean	Std Dev	Std Error	Minimum	Maximum
Control	5	19.60000000	0.54772256	0.24494897	19.00000000	20.00000000
100%	5	7.00000000	1.58113883	0.70710678	5.00000000	9.00000000

Variances	T	Method	DF	Prob>|T|
Unequal	16.8375	Satterthwaite	4.9	0.0001
		Cochran	4.0	0.0001
Equal	16.8375		8.0	0.0000

For HO: Variances are equal, F' = 8.33   DF = (4,4)   Prob>F' = 0.0640

Figure 13-2. Example Data Listing and SAS/PC Program for a t-Test between Treatments Based on Hypothetical Water-Column Bioassay Data in Table 13-2

Levene's Test on Water Column Bioassay Data

------------------------- Treatment Group=Control -------------------------

# of Survivors	Group Average	Absolute Deviation from Average
20	19.6	0.4
19	19.6	0.6
20	19.6	0.4
20	19.6	0.4
19	19.6	0.6

------------------------- Treatment Group=100% -------------------------

# of Survivors	Group Average	Absolute Deviation from Average
6	7.0	1.0
7	7.0	0.0
9	7.0	2.0
5	7.0	2.0
8	7.0	1.0

General Linear Models Procedure

Dependent Variable: DEVIATNS Absolute Deviation from Average

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.29600000	1.29600000	3.64	0.0928
Error	8	2.84800000	0.35600000		
Corrected Total	9	4.14400000			

(continued)

Figure 13-3. Example Data Listing and SAS/PC Program Output for a Levene's Homogeneity of Variance Test for a Hypothetical Water-Column Bioassay from Data in Table 13-2

	R-Square	C.V.	Root MSE		DEVIATNS Mean
	0.312741	71.03064	0.5966574		0.84000000
Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRTMNT	1	1.29600000	1.29600000	3.64	0.0928
Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRTMNT	1	1.29600000	1.29600000	3.64	0.0928

Figure 13-3. *(continued)* **Example Data Listing and SAS/PC Program Output for a Levene's Homogeneity of Variance Test for a Hypothetical Water-Column Bioassay from Data in Table 13-2**

In such cases, it is usually prudent to use the *t*-test for unequal variances. Choosing this approach, the *t*-test, assuming unequal variances, indicates a significant difference (Prob > $|T|$ = 0.0001) in survival between these two treatments. Significance probabilities for all of the *t*-tests in the SAS results are two-tailed probabilities. For this application, we are concerned about dredged-material samples with an effect greater than the control, and it is not important to detect dredged-material samples that have less effect than the control. To obtain the one-tailed or directional probabilities that we wish here, we divide the two-tailed probabilities by 2 and consider the sign of the *t* statistic. Here, we are comparing the response in the control to the response in the 100% concentration. In this case, the control mean is greater than the mean of the 100% concentration group and, therefore, the *t* statistic is positive. Considering the *t*-test for unequal variances, the results are significant ($p = 0.00005$) and in the direction that we consider important; i.e., there is statistically significant increased mortality in the 100% concentration.

The F' test of equality of variances, given by the SAS program, is sensitive to departures from the assumption that these samples have been taken from populations with an underlying normal probability distribution. Figure 13-3 presents the results of a Levene's test, which is not sensitive to this assumption for reasonable samples sizes. This test is based on an ANOVA of the absolute deviations of the responses from the response group mean. Larger sample variances indicate larger absolute deviations. Results of Levene's test show that there is weaker evidence (Pr > F = 0.093) than in the F' test that we should reject the hypothesis of equal variances. That is, if there really were no difference in variances, then the probability of obtaining an F value as large as or larger than the one obtained from these data is almost 10%. In this example, the *t*-test shows that there is a statistically significant difference between control and 100% concentration groups in the mean number of surviving organisms, whether or not equal variances are assumed for the two groups.

13.2.2 Calculating Median Lethal Concentration

In the Tier III water-column bioassays it is recommended (Section 11.1.5) that the median lethal concentration (LC_{50}) be calculated for each observation time of the experiment. Confidence intervals on these values are used to assess whether the toxicity of the dredged material exceeds the limiting permissible concentration (LPC). It is not possible to calculate every LC_{50} unless at least 50% of the test organisms die in at least one of the serial dilutions. Experience indicates that often this does not occur for earlier time periods. If it is not possible to calculate an LC_{50}, then the LC_{50} is assumed to be 100%.

LC_{50} calculations are recommended also for reference toxicant tests to determine the relative health of the organisms used in bioassay and bioaccumulation testing.

Table 13-2 gives examples of data from a 96-h water-column bioassay. We see from these data that intermediate concentrations of the dredged material show intermediate proportions of surviving test organisms. The aim, therefore, is to apply some statistical method to these data to estimate the LC_{50} concentration at which 50% of the animals in the population would die. Calculating a 95% confidence interval using the sample LC_{50} signifies that there is only a 5% probability that the interval contains the true LC_{50} of the population of test organisms.

Because opinions vary about the most appropriate statistical method for calculating the LC_{50}, this implementation manual recommends using two or more of the procedures in the following citations to calculate the LC_{50}. Stephan (1977) and Gelber *et al.* (1985) provide careful reviews of LC_{50} estimation procedures. In addition, EPA (1985) discusses in detail the mechanics of calculating the LC_{50} by using current methods and contains, as an appendix, computer programs for each statistical method.

Compliance with the regulations is determined according to the Tier III guidance in Section 6.1.

13.2.3 Tier III Benthic Bioassays

The objective of a statistical analysis of Tier III benthic-bioassay data is to determine the strength of the evidence for concluding that the dredged-material samples are significantly more toxic to marine benthic infauna than are the reference-sediment samples. The test procedure is described in Section 11.2.

This objective can be accomplished by using an analysis of variance (ANOVA) procedure and an associated multiple comparison procedure known as Dunnett's test. These statistical techniques are discussed by Snedecor and Cochran (1980), Steele and Torrie (1980), SAS Institute (1985), and Dunnett (1964).

Table 13-3 presents survival data from a hypothetical benthic bioassay. In this example, mean mortality in the control is less than 10%, indicating the acceptability of the test. The ANOVA procedure assumes that the survival responses are independently and normally distributed with a common variance among treatment levels. For instance, if X_{ij} is the survival response (such as number of survivors) for the ith treatment level and jth replicate, then we assume that the underlying distribution of X_{ij} is normal with mean μ_i and variance σ^2.

Table 13-3. Number of Survivors in the Hypothetical Benthic Bioassay

Replicate[a]	Treatments				
			Dredged-Material Locations		
	Reference	Control	Station 1	Station 2	Station 3
1	20	20	17	15	17
2	20	19	16	16	12
3	19	20	18	13	10
4	19	20	17	17	16
5	20	20	15	11	13

[a]20 animals per replicate at initiation of test

$$X_{ij} \sim N(\mu_i, \sigma_1) \quad .$$

In other words, the treatment levels can have different means, but all levels have the same variance. The assumptions of normality and constant variance are not always met. AlthoughANOVA is fairly robust to deviations from these assumptions when sample sizes are equal, a test of the validity of these assumptions is recommended before performing the ANOVA. Bartlett's test (Snedecor and Cochran, 1980), the F' test (Section 13.2.1), or Levene's test (Section 13.2.1) may be used to test for homogeneity of variances. If the raw data do not satisfy these assumptions, a mathematical transformation can sometimes be applied to the data, which will confer a more normal distribution to the transformed data and will stabilize the variance among treatment levels (Natrella, 1963). For example, a common transformation for proportions (such as percent survival) is

$$Y_{ij} = arcsine \sqrt{p_{ij}} \quad ,$$

where p_{ij} is the proportion of survivors at the ith treatment level and for the jth replicate, i.e., p_{ij} = X_{ij}/k. We recommend that the survival proportion be used as the treatment response for analysis. If the data do not satisfy the ANOVA assumptions of normality and constant variance, we recommend that the arcsine/square-root transformation presented above be used prior to performing the ANOVA, although any transformation that increases normality and stabilizes variance among treatments may be used.

Another common transformation used to stabilize the variance is the logarithmic transformation. It is used when the standard deviation increases in direct proportion to the mean, i.e., when those treatments with larger means also have larger standard deviations. The transformation is simply

$$Y_{ij} = \log(X_{ij}) \quad .$$

Either natural or base-10 logarithms are commonly used.

Figure 13-4 illustrates an SAS/PC program that performs an ANOVA on the transformed survival proportions calculated from Table 13-3. In addition to the ANOVA, this program includes an analysis of the total number of survivors using a nonparametric Kruskal-Wallis test (Daniel, 1978) for comparison. The nonparametric test often is performed when the distributional assumptions of the parametric ANOVA test cannot be verified. The nonparametric test can actually

be more powerful in detecting differences among treatment levels, depending on the underlying parametric probability distribution model.

The output from the program is given in Figures 13-5 through 13-9. Figure 13-5 presents the data on the number of survivors for each treatment, the proportion of survivors, and the arcsine/square-root transformed proportions. This output was produced by the PROC PRINT; statement in the program in Figure 13-4.

Figure 13-6 presents the arithmetic means and standard deviations of these variables. Note that the number of survivors is more variable (i.e., standard deviations are larger) in the Station treatment groups than in the reference-sediment treatment groups. Note also that the variability among treatment groups is more stable for the transformed survival proportions variable than among the proportions themselves. Output in Figure 13-6 is produced by the PROC MEANS; statement.

Figure 13-7 contains the ANOVA results. These results were produced by the PROC GLM; statement. The *F* value is the statistic of interest in these tables:

$$F = MST/MSE \quad ,$$

where *MST* is the mean square (variance) for differences among treatment level means (41.1 in this example with NUM_SIV as the dependent variable) and *MSE* is the mean square for differences among replicates (3.18 in this same example). If survival is unaffected by the treatment levels, *F* is approximately equal to 1.0. If survival is less among treatments levels, $F > 1.0$. The probability of obtaining an *F* statistic as large as or larger than the one calculated for the transformed data (i.e., $F = 22.06$) is 0.0001, as given by $Pr > F$ in the output. That is, if there is no difference in survival among the stations and controls, we would expect to observe survival data like those given in Table 13-3, only 1 in 10,000. Thus, we reject the hypothesis of equal survival rates at the 0.0001 level of significance.

In this example, there is strong evidence for concluding that there are significant differences in survival among the reference-sediment and dredged-material treatment groups. This conclusion would have been reached whether or not the data are were transformed (Figure 13-7). It is also important to know which sampling stations differed significantly from the reference. The results of an appropriate multiple-comparison analysis known as Dunnett's test (Dunnett, 1964) are given in Figure 13-8. This test was requested in the SAS statements specifying the ANOVA, and the results show that there is no difference in survival between the control group and the reference sediment group either for transformed or untransformed data. The negative differences between

```
********************************************************************
*  This SAS program performs a parametric analysis of variance    *
*  (ANOVA) and a nonparametric Kruskal-Wallis test to compare the *
*  average number of surviving organisms in a series of treatment *
*  groups using hypothetical Benthic Bioassay data.  The sample   *
*  treatment averages and standard deviations are also displayed. *
*  For the parametric ANOVA, the program also performs Dunnett's  *
*  test to determine which non-control stations (if any) have     *
*  averages which significantly differ from the reference sample. *
********************************************************************;
options nodate nonumber linesize=80 pagesize=60;

 /* Identify the treatment group codes */
proc format;
  value trtfmt 1='Reference'
               2='Control'
               3='Statn. 1'
               4='Statn. 2'
               5='Statn. 3';

 /* Input the bioassay data after the CARDS; statement, listing the */
 /* treatment group code, then the number of survivors in the group */
data solphase;
  input trtmnt num_sviv @@;
  prp_sviv = num_sviv/20;            /* Proportion of survivors */
  trn_sviv = arsin(sqrt(prp_sviv));  /* Arcsine transformation of the */
                                     /* proportion                    */
  label trtmnt='Treatment Group'
        num_sviv='# of survivors'
        prp_sviv='Proportion of survivors'
        trn_sviv='Transformed survivorship proportion';
  format trtmnt trtfmt.;
  CARDS;
1 20 1 20 1 19 1 19 1 20
2 20 2 19 2 20 2 20 2 20
3 17 3 16 3 18 3 17 3 15
4 15 4 16 4 13 4 17 4 11
5 17 5 12 5 10 5 16 5 13
;

proc sort data=solphase;
  by trtmnt;

 /* Print out the bioassay data */
PROC PRINT data=solphase label noobs;
  var num_sviv prp_sviv trn_sviv;
  by trtmnt;
  format prp_sviv trn_sviv 5.3;
  title 'Listing of Hypothetical Benthic Bioassay Data';
```

(continued)

Figure 13-4. Example SAS/PC Program for Analyzing Survival Proportion from the Hypothetical Benthic Bioassay Data in Table 13-3

```
 /* Obtain the mean number and percentage of survivors per treatment group */
PROC MEANS data=solphase noprint;
  var num_sviv prp_sviv trn_sviv;
  by trtmnt;
  output out=meanout mean=m_n m_p m_t
                     std=s_n s_p s_t;

PROC PRINT data=meanout label noobs;
  var trtmnt m_n s_n m_p s_p m_t s_t;
  label m_n='Avg. # survivors'
        s_n='Std. Dev. for # survivors'
        m_p='Avg. prop. survivors'
        s_p='Std. Dev. for prop. survivors'
        m_t='Avg. transformed prop.'
        s_t='Std. Dev. for transformed prop.';
  format m_n 4.1  m_p 5.3  m_t s_n s_p s_t 5.3;
  title1 'Average and Standard Deviations of Hypothetical Benthic Bioassay';
  title2 'Data, Calculated by Treatment Group';

 /* Perform a parametric one-way ANOVA, with Dunnett's multiple comparisons */
 /* test, to determine differences between treatment groups in each of the  */
 /* responses.  Dunnett's test determines differences between each           */
 /* treatment group and the reference sample.                                */
PROC GLM order=internal data=solphase;
  class trtmnt;
  model num_sviv trn_sviv = trtmnt;  /* Use transformed proportion response */
  means trtmnt/DUNNETTL;
  title
  'Parametric one-way ANOVA on the Hypothetical Benthic Bioassay Data';
  title2 'to determine differences among treatment groups';

 /* Perform a nonparametric one-way ANOVA (Kruskal-Wallis test) on the   */
 /* numbers of survivors to test for differences among treatment groups. */
 /* A nonparametric test is considered due to possible lack of normality */
 /* in the numbers of survivors.                                         */
PROC NPAR1WAY wilcoxon data=solphase;
  class trtmnt;
  var num_sviv;
  title1
  'Nonparametric one-way ANOVA on the Hypothetical Benthic Bioassay Data';
  title2 'to determine differences among treatment groups';
run;
```

Figure 13-4. *(continued)* **Example SAS/PC Program for Analyzing Survival Proportion from the Hypothetical Benthic Bioassay Data in Table 13-3**

Listing of Hypothetical Benthic Bioassay Data

------------------------- Treatment Group=Reference -------------------------

# of survivors	Proportion of survivors	Transformed survivorship proportion
20	1.000	1.571
20	1.000	1.571
19	0.950	1.345
19	0.950	1.345
20	1.000	1.571

-------------------------- Treatment Group=Control --------------------------

# of survivors	Proportion of survivors	Transformed survivorship proportion
20	1.000	1.571
19	0.950	1.345
20	1.000	1.571
20	1.000	1.571
20	1.000	1.571

-------------------------- Treatment Group=Statn. 1 -------------------------

# of survivors	Proportion of survivors	Transformed survivorship proportion
17	0.850	1.173
16	0.800	1.107
18	0.900	1.249
17	0.850	1.173
15	0.750	1.047

(continued)

Figure 13-5. Example Data Listing from an SAS/PC Program Showing the Treatment Level (TRTMNT), Number of Survivors (NUM_SVIV), Survival Proportions (PRP_SVIV), and the Transformed Proportions (TRN_SVIV) from the Hypothetical Data Given in Table 13-3

------------------------- Treatment Group=Statn. 2 -------------------------

# of survivors	Proportion of survivors	Transformed survivorship proportion
15	0.750	1.047
16	0.800	1.107
13	0.650	0.938
17	0.850	1.173
11	0.550	0.835

Listing of Hypothetical Benthic Bioassay Data

------------------------- Treatment Group=Statn. 3 -------------------------

# of survivors	Proportion of survivors	Transformed survivorship proportion
17	0.850	1.173
12	0.600	0.886
10	0.500	0.785
16	0.800	1.107
13	0.650	0.938

Figure 13-5. *(continued)* **Example Data Listing from an SAS/PC Program Showing the Treatment Level (TRTMNT, Number of Survivors (NUM_SVIV), Survival Proportions (PRP_SVIV), and the Transformed Proportions (TRN_SVIV) from the Hypothetical Data Given in Table 13-3**

Average and Standard Deviations of Hypothetical Benthic Bioassay Data, Calculated by Treatment Group

Treatment Group	Avg. # survivors	Std. Dev. for # survivors	Avg. prop. survivors	Std. Dev. for prop. survivors	Avg. transformed prop.	Std. Dev. for transformed prop.
Reference	19.6	0.548	0.980	0.027	1.481	0.124
Control	19.8	0.447	0.990	0.022	1.526	0.101
Statn. 1	16.6	1.140	0.830	0.057	1.150	0.076
Statn. 2	14.4	2.408	0.720	0.120	1.020	0.135
Statn. 3	13.6	2.881	0.680	0.144	0.978	0.160

Figure 13-6. Example SAS/PC Listing of Arithmetic Means and Standard Deviations for Hypothetical Benthic Bioassay Data Given in Table 13-3

Parametric one-way ANOVA on the Hypothetical Benthic Bioassay Data
to determine differences among treatment groups

General Linear Models Procedure

Dependent Variable: NUM_SVIV # of survivors

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	164.40000000	41.10000000	12.92	0.0001
Error	20	63.60000000	3.18000000		
Corrected Total	24	228.00000000			

R-Square	C.V.	Root MSE	NUM_SVIV Mean
0.721053	10.61462	1.7832555	16.80000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRTMNT	4	164.40000000	41.10000000	12.92	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRTMNT	4	164.40000000	41.10000000	12.92	0.0001

General Linear Models Procedure

Dependent Variable: TRN_SVIV Transformed survivorship proportion

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.32120960	0.33030240	22.06	0.0001
Error	20	0.29948815	0.01497441		
Corrected Total	24	1.62069775			

R-Square	C.V.	Root MSE	TRN_SVIV Mean
0.815210	9.941941	0.1223700	1.23084575

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRTMNT	4	1.32120960	0.33030240	22.06	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRTMNT	4	1.32120960	0.33030240	22.06	0.0001

Figure 13-7. Example SAS/PC Program Output Showing ANOVA Results for Hypothetical Benthic Bioassay Data Given in Table 13-3

Parametric one-way ANOVA on the Hypothetical Benthic Bioassay Data to determine differences among treatment groups

General Linear Models Procedure

Dunnett's One-tailed T tests for variable: NUM_SVIV

NOTE: This tests controls the type I experimentwise error for comparisons of all treatments against a control.

Alpha= 0.05 Confidence= 0.95 df= 20 MSE= 3.18
Critical Value of Dunnett's T= 2.304
Minimum Significant Difference= 2.599

Comparisons significant at the 0.05 level are indicated by '***'.

TRTMNT Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
Control - Reference	-2.399	0.200	2.799	
Statn. 1 - Reference	-5.599	-3.000	-0.401	***
Statn. 2 - Reference	-7.799	-5.200	-2.601	***
Statn. 3 - Reference	-8.599	-6.000	-3.401	***

Parametric one-way ANOVA on the Hypothetical Benthic Bioassay Data to determine differences among treatment groups

General Linear Models Procedure

Dunnett's One-tailed T tests for variable: TRN_SVIV

NOTE: This tests controls the type I experimentwise error for comparisons of all treatments against a control.

Alpha= 0.05 Confidence= 0.95 df= 20 MSE= 0.014974
Critical Value of Dunnett's T= 2.304
Minimum Significant Difference= 0.1783

Comparisons significant at the 0.05 level are indicated by '***'.

TRTMNT Comparison	Simultaneous Lower Confidence Limit	Difference Between Means	Simultaneous Upper Confidence Limit	
Control - Reference	-0.1332	0.0451	0.2234	
Statn. 1 - Reference	-0.5090	-0.3307	-0.1523	***
Statn. 2 - Reference	-0.6388	-0.4605	-0.2821	***
Statn. 3 - Reference	-0.6810	-0.5027	-0.3244	***

Figure 13-8. Example SAS/PC Program Output Showing Dunnett's Test for Hypothetical Benthic Bioassay Given in Table 13-3

Nonparametric one-way ANOVA on the Hypothetical Benthic Bioassay Data
to determine differences among treatment groups

N P A R 1 W A Y P R O C E D U R E

Wilcoxon Scores (Rank Sums) for Variable NUM_SVIV
Classified by Variable TRTMNT

TRTMNT	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
Referenc	5	100.000000	65.0	14.5028733	20.0000000
Control	5	105.000000	65.0	14.5028733	21.0000000
Statn. 1	5	55.500000	65.0	14.5028733	11.1000000
Statn. 2	5	34.500000	65.0	14.5028733	6.9000000
Statn. 3	5	30.000000	65.0	14.5028733	6.0000000

Average Scores were used for Ties

Kruskal-Wallis Test (Chi-Square Approximation)
CHISQ= 19.286 DF= 4 Prob > CHISQ= 0.0007

Figure 13-9. Example SAS/PC Program Output Showing Nonparametric (Kruskal-Wallis) Test Results for Hypothetical Benthic Bioassay Data Given in Table 13-3

means and the significance denoted by the asterisks indicate that survival in each dredged-materialtreatment group is significantly lower than in the reference group. If all the treatment groups (including the reference) actually had the same mean survival, then the probability of concluding that any dredged-material treatment group has a lower mean survival than the reference is 0.05.

The Dunnett's test in the SAS program in Figure 13-4 compares all subsequent treatment groups to the first group in the dataset, that in this case is the reference sediment. *If other software is used, care has to be taken to see that comparisons are made to reference, not control, data.*

Finally, because the number of survivors in each treatment group is not always normally distributed, we have also performed a nonparametric test that does not require the assumption of normality. Figure 13-9 shows the results from a nonparametric Kruskal-Wallis test which was generated by the PROC NPAR1WAY WILCOXON; statement. This test is a counterpart to the parametric ANOVA procedure. It is based on the sum of the ranks for all observations in each treatment group. If survival is consistently lower in the station treatment groups, the sum of the ranks will be smaller. The Kruskal-Wallis statistic is approximately distributed as a chi-square random variable -- hence, the probability of obtaining as much or more evidence (CHISQ = 19.286) in favor of a difference in survival among the reference and station treatment groups when, in fact, there is no difference is 0.0007, or about 7 times in 10,000. This very small probability is strong evidence that sediments from the proposed dredging site in our hypothetical example truly are more toxic than the reference sediment.

Compliance with the regulations is determined according to the Tier III guidance in Section 6.2.

13.3 BIOACCUMULATION

Bioaccumulation tests described in Section 11 are applied to determine whether an organism's exposure to the dredged material is likely to cause an elevation of contaminants in its body, i.e., is bioaccumulation likely to occur in organisms exposed to the dredged material. Bioaccumulation tests conducted in the laboratory or in the field require statistical analysis as described in Sections 13.3.1 through 13.3.3.

Table 13-4. Results from a Hypothetical Single-Time Point Bioaccumulation Test, Showing Average Contaminant Concentrations (μg/g dry weight) in Tissues of Animals Exposed to Different Treatments

Replicate[a]			Dredged-Material Samples		
	Reference	Control	1	2	3
1	0.06	0.04	0.16	0.24	0.13
2	0.05	0.03	0.19	0.10	0.05
3	0.05	0.09	0.18	0.13	0.17
4	0.08	0.04	0.22	0.18	0.08
5	0.09	0.05	0.31	0.30	0.22
n	5		5	5	5
Mean	0.066		0.212	0.190	0.130
Standard error	0.008		0.026	0.036	0.030
Upper 95%, one-sided confidence limit	0.083				
Lower 95%, one-sided confidence limit			0.156	0.113	0.065

[a]20 animals per replicate

13.3.1 Tier III 10- or 28-Day Single-Time Point Laboratory Study

The Tier III single-time point laboratory bioaccumulation test produces tissue concentration measurements for each contaminant of concern. Table 13-4 presents the results from a hypothetical laboratory test. Chemical analysis of the tissue samples from each replicate shows varying concentrations of the example contaminant.

13.3.1.1 Comparisons with a Reference Sediment

The objective of this type of analysis is to determine whether organisms exposed to the dredged material have a greater bioaccumulation of contaminants than organisms exposed to the reference sediment. One-sided tests are appropriate because there is little concern if the effect of the dredged material is less than the reference sediment.

The ANOVA procedure in Section 13.2.3 is appropriate to use on these data to compare differences among treatment groups, followed by Dunnett's test to compare individual treatments with the reference sediment. The same type of SAS program as in Figure 13-4 can be used to perform the ANOVA, except that the statement in PROC GLM performing Dunnett's test should be replaced by

```
means/dunnettu;
```

This replacement is necessary because we are testing whether any treatment (dredged material at any sampling station) has a larger effect than the reference.

13.3.1.2 Comparisons with an Action Level

In this comparison, the objective is to determine whether the mean bioaccumulation of contaminants in animals exposed to a dredged material is greater than a prespecified action level.

If the dredged material to be used for testing is taken from several dredging stations (e.g., three points within a harbor), then a confidence-interval approach is appropriate.

If the confidence interval for the concentration from a dredged-material exposure contains the FDA level (i.e., the lower confidence interval is less than the FDA level), there is no statistically significant difference between the concentration from the dredged material and the FDA action level (Table 6-1). Conversely, if the FDA level falls below the lower-level confidence interval, the concentration from the dredged material is statistically significantly higher than the FDA action

level. One-sided confidence levels are appropriate since there is concern only if the effect in the dredged material is greater than the action level.

The statistics needed for the calculation of confidence levels include the mean and the standard error. These calculations are simple, especially with a small sample size, and can be calculated with paper and pencil. Many calculators include programmed mean and standard-deviation calculations. The sequence of calculations necessary for the statistical analysis is given in the following.

p = Number of stations from which dredged material is taken

n = Number of observations at a particular station

x_{nj} = njth observation, e.g., x_2 is the second observation

Σx = Every x summed $= x_1 + x_2 + x_3 + \ldots + x_n$

Σx^2 = Every x squared $= (x_1)(x_1) + (x_2)(x_2) + \ldots + (x_n)(x_n)$

Mean = $\Sigma x / n$

Variance = $[\Sigma x^2 - (\Sigma x)^2/n] / [n - 1]$

Standard deviation = $(\text{variance})^{\frac{1}{2}}$

Standard error = standard deviation / standard deviation/$(n)^{\frac{1}{2}}$

$t_{\alpha,n-1} = 1 - \alpha)$ quantile of the Student's-t distribution with $m - 1$ degrees of freedom.

Lower 95%, one-sided confidence level = mean $- (t_{0.10/p,n-1})$(std. error)

The t-distribution resembles the normal distribution in that it is bell-shaped. This distribution, rather than the normal distribution, is used in situations when the population variance of the distribution is not known and is estimated from the sample values. The t value to use depends on two parameters: α (the probability of a Type I error for a single t-test) and the number of degrees of freedom. In the application presented here, the number of degrees of freedom is always one less than the number of observations, i.e., $n - 1$. The value of α depends on the probability desired in the tails of the distribution. Here, we are interested in simutaneous 95% one-sided confidence levels; i.e., we want an overall probability of 0.05 of concluding that the mean of at least one of the stations is higher than the action level if, in fact, all of the treatment means are less than the action level. The $t_{\alpha,f}$ quantiles for various α and degrees of freedom f are available in most elementary texts on statistics or can be calculated directly by using one of many statistical software packages [e.g., tinv( ) in PC SAS]. Table 13-5 gives an abbreviated t distribution table. The t value that will give simultaneous 95%, one-sided confidence levels (calculated on for five observations) for the concentrations on each of 3 on each of 5 dredging stations is 3.186 ($\alpha = 0.05/3$ with $n - 1 = 4$ degrees of freedom).

Table 13-5. Selected Values of the Two-Tailed *t* Distribution

Degrees of Freedom	Value of *t* Distribution[a]
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812

[a]Two-tailed probability: 0.10
One-tailed probability: 0.05

Figure 13-10 shows the relationship of bioaccumulation in the various dredged-material samples to the FDA action level. Average tissue concentration in dredged-material sample number 1 is numerically higher than the FDA action level, whereas the average tissue concentration in dredged-material samples 2 and 3 is below the FDA action level. Bioaccumulation from the dredged material does not statistically exceed bioaccumulation from the reference sediment; i.e., the confidence levels of sample 3 and the reference sediment overlap.

We use simultaneous confidence intervals to control the overall confidence level. If we have p dredging stations and place a $(1 - 0.05/p) \times 100\%$ confidence interval on the average concentration of each station, then the overall confidence level that all p intervals contain the true concentration for their respective stations is at least 95%. Thus, we can draw conclusions on whether each station's true concentration is significantly different from the FDA action level by noting whether the confidence interval contains the FDA level, and our overall conclusion will have an overall Type I error probability of no more than 0.05. If we simply calculated 95% confidence intervals for each station, then the probability of making a Type I error of incorrectly noting a significance between the FDA level and the mean for a station will be higher than 0.05. The simultaneous confidence intervals in Figure 13-10 reflect three stations; thus, each individual confidence interval is done at the $0.05/3 = 0.017$ confidence level. This method of determining simultaneous confidence intervals is known as the Bonferroni method and is discussed by Snedecor and Cochran (1980).

Compliance with the regulations is determined according to the Tier III bioaccumulation guidance in Section 6.3.

13.3.2 Tier IV Time-Series Laboratory Bioaccumulation Study

The 28-day time-series laboratory bioaccumulation test in Tier IV is designed to detect differences, if any, between steady-state bioaccumulation in organisms exposed to the dredged material and steady-state bioaccumulation in organisms exposed to the reference sediment. If organisms are exposed to biologically available contaminants under constant conditions for a sufficient period of time, bioaccumulation will eventually reach a steady state in which maximum bioaccumulation has occurred, and the net exchange of the contaminant between sediment or dredged material and the organism is zero.

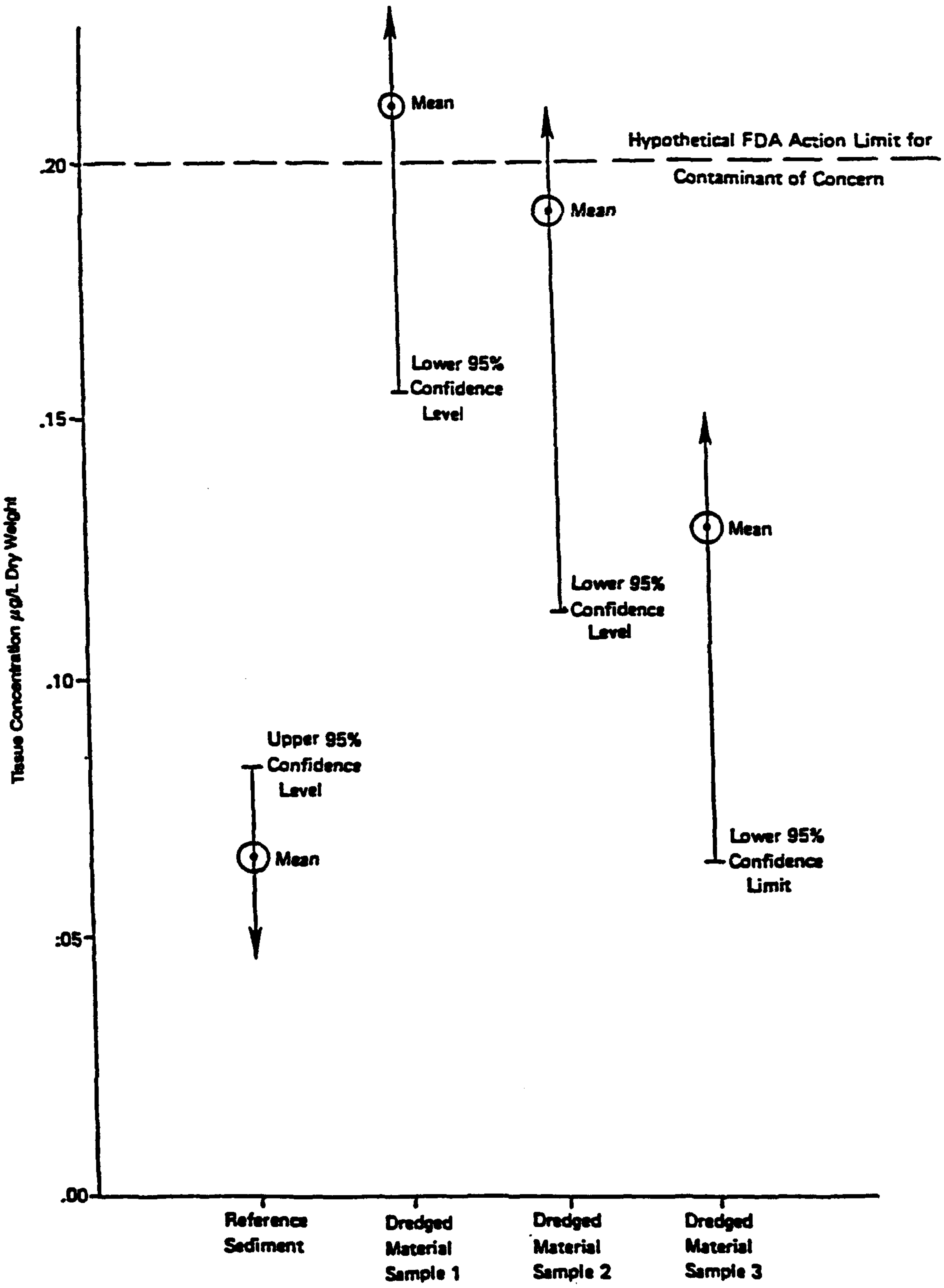

Figure 13-10. Mean Tissue Concentration with 95% One-Sided Confidence Intervals Calculated on Hypothetical Single-Time Point Bioaccumulation Data Given in Table 13-4

A simple kinetic model (McFarland *et al.*, 1986; McFarland and Clarke, 1987) can be used with data collected over a relatively short period of constant exposure to project tissue concentrations at steady state. This model integrated for constant exposure is

$$C_t = \frac{k_1 C_w}{k_2}(1 - e^{-k_2 t}) \quad ,$$

where C_t is the concentration of a compound in tissues of an organism at time t, k_1 is the uptake rate constant, C_W is the exposure concentration of the compound, k_2 is the elimination rate constant, and t is the time.

As duration of exposure increases, the exponential term in the model approaches zero, and the tissue concentration at steady state (i.e., infinite exposure) is calculated as

$$C_t = \frac{k_1 C_w}{k_2} = C_{ss}$$

where C_{SS} is an estimate of the whole-body concentration of the compound at steady state (i.e., after infinitely long constant exposure).

Table 13-6 presents tissue concentrations resulting from a hypothetical 28-day time-series laboratory bioaccumulation test on three dredged-material samples. There are five replicates of each treatment, and tissue samples were analyzed on Days 2, 4, 7, 10, 18, and 28 of the test. Mortality in all replicates did not exceed 25%, and therefore the test is acceptable.

These data can be used with iterative nonlinear regression methods such as those in the SAS NLIN procedure to solve for the parameters in the model above. Then C_{SS}, the steady-state concentration, is simply the ratio of the estimated nonlinear regression parameters k_1 and k_2 together with C_W. In this iterative calculation method, the contaminant concentration in the sediment is used as C_W. Figure 13-11 provides an SAS/PC program to carry out these calculations. Iterative curve-fitting techniques will provide better fits to some data than to others. If difficulties are encountered, approaches such as those discussed by SCI (1989) and Draper and Smith (1981) should be considered. The advice of an applied statistician might be appropriate.

Figures 13-12 through 13-17 present the results of the SAS program shown in Figure 13-11. Figure 13-12 is a list of the data used in the program. Figures 13-13 through 13-16

Table 13-6. **Average Tissue Concentration Resulting from a Hypothetical 28-Day Time-Series Bioaccumulation Test, Showing Different Contaminant Concentrations in Tissues of Animals Exposed to Different Treatments[a]**

Day	Replicate	Reference	Dredged Material Samples		
			A	B	C
2	1	0.054	0.159	0.869	0.745
2	2	0.163	0.292	0.726	1.703
2	3	0.391	0.428	0.394	2.045
2	4	0.734	0.558	1.232	1.855
2	5	0.634	0.256	0.977	.135
4	1	0.441	0.516	0.838	1.316
4	2	0.797	0.158	0.633	0.930
4	3	0.203	0.743	0.452	2.141
4	4	0.564	0.324	0.728	1.150
4	5	0.018	0.126	1.314	1.621
7	1	0.687	0.881	1.246	1.583
7	2	0.177	0.317	0.816	2.715
7	3	0.862	0.270	0.897	1.016
7	4	0.413	0.562	1.639	2.221
7	5	0.029	0.095	0.688	2.134
10	1	0.037	0.278	1.767	1.578
10	2	0.549	0.485	1.272	2.268
10	3	0.884	0.051	1.003	1.756
10	4	0.787	0.909	1.158	2.899
10	5	0.294	0.718	1.415	0.890
18	1	0.856	0.904	1.631	2.822
18	2	0.598	1.300	1.877	2.607
18	3	0.016	0.671	1.487	3.414
18	4	0.806	0.234	1.216	1.319
18	5	0.119	0.337	1.280	1.866
28	1	0.514	0.172	1.178	1.295
28	2	0.839	1.049	1.721	2.964
28	3	0.793	0.476	1.366	2.109
28	4	0.099	0.712	1.513	2.820
28	5	0.226	1.245	1.843	3.325
Mean sediment concentration		0.4	54.0	33.0	44.0

[a] Total contaminant concentration in micrograms per gram dry weight.
Reference Sediment Statistics
Steady-state mean tissue concentration: 0.473 g/g.
Steady-state upper 95%, one-sided confidence level: 0.590.
Hypothetical FDA action level: 2 μg/g

give the nonlinear regression analyses for the reference and dredged materials A, B, and C, respectively. Results of the regression analyses are listed in Figure 13-17.

In the data listing in Figure 13-12, a value of 999 days is used to represent time infinity at which steady-state concentrations would have occurred.

The confidence levels calculated by the SAS nonlinear regression procedure are 95%, two-sided confidence levels. A one-sided confidence level is calculated from the two-sided levels in the SAS statements in the last data step of the program. The SAS statement incorporate *t* values for two-sided levels (*t* value: 2.048; *p* level: 0.05 with 28 degrees of freedom) and for one-sided levels [*t* value: 1.701 (Figure 13-12); *p* level: 0.10 with 28 degrees of freedom]. If other than five replicates on each of 6 days (resulting in 30 observations included in the nonlinear regression analysis) are used, these *t* values have to be altered to reflect the correct number of degrees of freedom. which is two less than the total number of observations.

The summary in Figure 13-17 gives the value of the tissue concentration (pre_ct) predicted by nonlinear regression for each day of the test and for steady-state (estimated at 999 days). The summary also includes the corresponding upper and lower 95%, one-sided confidence levels (up_95_1s and lo_95_1s). The predicted steady-state concentrations and their lower confidence levels are compared to FDA action levels and to the upper confidence level calculated on steady-state reference-sediment bioaccumulation.

Figure 13-18 graphically displays the results of the nonlinear regressions of tissue concentration over time for the four treatments. The nonlinear regression line for each treatment is shown with the lower 95% one-sided confidence bounds on the sample means. The regression line and confidence bounds for the reference treatment are solid lines. The lines for treatment A are dotted, for treatment B are dashed, and for treatment C are long and short dashes. Because bounds have been drawn beyond the time frame of the laboratory test (28 days) to illustrate the steady-state tissue concentration. The hypothetical FDA action level is shown on Figure 13-18 for comparison.

From Figure 13-18, it can be seen that at steady-state bioaccumulation from dredged-material sample A does not differ from the reference sediment; i.e., the 95% one-sided confidence interval of treatment A overlaps the confidence interval of the reference sediment. At steady-state, the lower bound of sample A is less than the upper bound of the reference sediment. Figure 13-18 also illustrates that the steady state tissue concentration of sample A is less than the FDA action level. For samples B and C, the lower 95% one-sided confidence bounds on concentration at steady state are completely above the confidence bounds of the reference sediment. Since there is no overlap of confidence bounds at steady state, samples B and C differ from the reference sediment at the statistical significance level of 0.05.

```
*********************************************************************
*  This SAS program performs a nonlinear regression analysis to fit *
*  a simple kinetic model on hypothetical 28-day bioaccumulation    *
*  laboratory test data.  This analysis determines if there are     *
*  differences between steady state bioaccumulation in organisms    *
*  exposed to dredged material and in organisms exposed to          *
*  reference sediment.  This program also calculates one-sided 95%  *
*  confidence levels from the two-sided levels calculated by PROC   *
*  NLIN.  The program assumes a sample size of five.                *
*********************************************************************;
options nodate nonumber linesize=80 pagesize=60;

 /* Identify the station codes */
proc format;
  value $trtfmt 'R'='Reference'
                'A'='Station A'
                'B'='Station B'
                'C'='Station C';

 /* Input the bioaccumulation data after the CARDS; statement, listing the */
 /* station code, the day of measurement, and the tissue concentration.   */
data bioaccum;
  input trtmnt $ t_days c1-c5 @@;
  array cs{5} c1-c5;

 /* Input the mean sediment concentration in the following SELECT statement */
  select (trtmnt);
     when ('R') conc_sed = 0.45;  /* Reference sediment concentration */
     when ('A') conc_sed = 4.0;   /* Station A sediment concentration */
     when ('B') conc_sed = 33.;   /* Station B sediment concentration */
     when ('C') conc_sed = 44.;   /* Station C sediment concentration */
     otherwise;
  end;

  /* Output one line per measurement */
  do rep=1 to 5;
     conc_tis = cs{rep};
     output;
  end;

  keep trtmnt t_days conc_sed rep conc_tis;
  format trtmnt $trtfmt.;
  label trtmnt='Treatment Level'
        t_days='  Time (days) '
        conc_sed='  Sediment Concentration '
        rep='Replicate Number'
        conc_tis='Tissue Concentration';

  CARDS;
R  2 0.054 0.163 0.391 0.734 0.634    R  4 0.441 0.797 0.203 0.564 0.018
R  7 0.687 0.177 0.862 0.413 0.029    R 10 0.037 0.549 0.884 0.787 0.294
R 18 0.856 0.598 0.016 0.806 0.119    R 28 0.514 0.839 0.793 0.099 0.226
```

(continued)

Figure 13-11. Example SAS/PC Program To Perform Nonlinear Regression Analysis Using Hypothetical 28-Day Time-Series Bioaccumulation Data

```
A  2 0.159 0.292 0.428 0.558 0.256     A  4 0.516 0.158 0.743 0.324 0.126
A  7 0.881 0.317 0.270 0.562 0.095     A 10 0.278 0.485 0.051 0.909 0.718
A 18 0.904 1.300 0.671 0.234 0.337     A 28 0.172 1.049 0.476 0.712 1.245
B  2 0.869 0.726 0.394 1.232 0.977     B  4 0.838 0.633 0.452 0.728 1.314
B  7 1.246 0.816 0.897 1.639 0.688     B 10 1.767 1.272 1.003 1.158 1.415
B 18 1.631 1.877 1.487 1.216 1.280     B 28 1.178 1.721 1.366 1.513 1.843
C  2 0.745 1.703 2.045 1.855 1.135     C  4 1.316 0.930 2.141 1.150 1.621
C  7 1.583 2.715 1.016 2.221 2.134     C 10 1.578 2.268 1.756 2.899 0.890
C 18 2.822 2.607 3.414 1.319 1.866     C 28 1.295 2.964 2.109 2.820 3.325
;
proc sort data=bioaccum;
  by trtmnt conc_sed t_days rep;

 /* Print the input data */
PROC PRINT data=bioaccum label noobs;
  var rep conc_tis;
  by trtmnt conc_sed t_days;
  title 'Listing of 28-Day Bioaccumulation Data';

 /* Fit the simple kinetic model on the data */
data bioaccum;
  set bioaccum;
  by trtmnt;
  output;
  if (last.trtmnt) then do;
                         t_days = 999;
                         rep = 1;
                         conc_tis = .;
                         output;
                         end;

PROC NLIN data=bioaccum method=marquardt;
  by trtmnt;
  parameters k1=0.1 k2=0.5;
  kicks = k1*conc_sed/k2;
  exp_term = exp(-k2*t_days);
  model conc_tis = kicks*(1-exp_term);
  der.k1 = (conc_sed/k2) * (1-exp_term);
  der.k2 = kicks * (-1/k2 + exp_term/k2 + t_days*exp_term);
  output out=results
         p=pred_ct 195m=lo_95_2s u95m=up_95_2s;
  title 'Fitting of Kinetic Model to the Bioaccumulation Data';

 /* Calculate the 95% one-sided confidence levels based on the */
 /* two-sided levels calculated by PROC NLIN.                  */

proc means data=results noprint;
  var conc_tis;
  by trtmnt;
  output out=nreps n=n;
```

(continued)

Figure 13-11. Example SAS/PC Program To Perform Nonlinear Regression Analysis Using Hypothetical *(continued)* 28-Day Time-Series Bioaccumulation Data

```
data results2;
  merge results nreps;
  by trtmnt;
  if (rep = 1);
  df = n - 2;
  t_05 = tinv(0.975,df);
  t_10 = tinv(0.95,df);
  lo_95_1s = pred_ct - (up_95_2s - pred_ct)*t_10/t_05;
  up_95_1s = pred_ct + (up_95_2s - pred_ct)*t_10/t_05;
  label pred_ct='Predicted Concentration'
        lo_95_1s='Lower 95% Conf. Bound on the Concentration'
        up_95_1s='Upper 95% Conf. Bound on the Concentration';

proc sort data=results2;
  by trtmnt conc_sed t_days;

PROC PRINT data=results2 label noobs;
  var t_days pred_ct lo_95_1s up_95_1s;
  by trtmnt conc_sed;
  format pred_ct lo_95_1s up_95_1s 6.4;
  title 'Listing of Predicted Tissue Concentrations and One-Sided 95%';
  title2 'Confidence Intervals, Based on the Fitted Kinetic Model';
run;
```

Figure 13-11. Example SAS/PC Program To Perform Nonlinear Regression Analysis Using Hypothetical *(continued)* 28-Day Time-Series Bioaccumulation Data

Listing of 28-Day Bioaccumulation Data

----- Treatment Level=Station A Sediment Concentration=4 Time (days)=2 -----

Replicate Number	Tissue Concentration
1	0.159
2	0.292
3	0.428
4	0.558
5	0.256

----- Treatment Level=Station A Sediment Concentration=4 Time (days)=4 -----

Replicate Number	Tissue Concentration
1	0.516
2	0.158
3	0.743
4	0.324
5	0.126

----- Treatment Level=Station A Sediment Concentration=4 Time (days)=7 -----

Replicate Number	Tissue Concentration
1	0.881
2	0.317
3	0.270
4	0.562
5	0.095

---- Treatment Level=Station A Sediment Concentration=4 Time (days)=10 -----

Replicate Number	Tissue Concentration
1	0.278
2	0.485
3	0.051
4	0.909
5	0.718

(continued)

Figure 13-12. Example Data Listing from SAS/PC Program Showing Sediment Concentration (CONC_SED), Treatment Level (TRTMNT), Time in Days (T_DAYS), and Tissue Concentration (CONC_TIS) for Hypothetical 28-Day Bioaccumulation Laboratory Test Data

---- Treatment Level=Station A   Sediment Concentration=4   Time (days)=18 -----

Replicate Number	Tissue Concentration
1	0.904
2	1.300
3	0.671
4	0.234
5	0.337

---- Treatment Level=Station A   Sediment Concentration=4   Time (days)=28 -----

Replicate Number	Tissue Concentration
1	0.172
2	1.049
3	0.476
4	0.712
5	1.245

---- Treatment Level=Station B   Sediment Concentration=33   Time (days)=2 -----

Replicate Number	Tissue Concentration
1	0.869
2	0.726
3	0.394
4	1.232
5	0.977

---- Treatment Level=Station B   Sediment Concentration=33   Time (days)=4 -----

Replicate Number	Tissue Concentration
1	0.838
2	0.633
3	0.452
4	0.728
5	1.314

(continued)

Figure 13-12. Example Data Listing from SAS/PC Program Showing Sediment Concentration (CONC_SED), *(continued)* Treatment Level (TRTMNT), Time in Days (T_DAYS), and Tissue Concentration (CONC_TIS) for Hypothetical 28-Day Bioaccumulation Laboratory Test Data

```
---- Treatment Level=Station B   Sediment Concentration=33   Time (days)=7 -----

                   Replicate      Tissue
                    Number     Concentration

                      1           1.246
                      2           0.816
                      3           0.897
                      4           1.639
                      5           0.688

---- Treatment Level=Station B   Sediment Concentration=33   Time (days)=10 ----

                   Replicate      Tissue
                    Number     Concentration

                      1           1.767
                      2           1.272
                      3           1.003
                      4           1.158
                      5           1.415

---- Treatment Level=Station B   Sediment Concentration=33   Time (days)=18 ----

                   Replicate      Tissue
                    Number     Concentration

                      1           1.631
                      2           1.877
                      3           1.487
                      4           1.216
                      5           1.280

---- Treatment Level=Station B   Sediment Concentration=33   Time (days)=28 ----

                   Replicate      Tissue
                    Number     Concentration

                      1           1.178
                      2           1.721
                      3           1.366
                      4           1.513
                      5           1.843
```

(continued)

Figure 13-12. Example Data Listing from SAS/PC Program Showing Sediment Concentration (CONC_SED), *(continued)* Treatment Level (TRTMNT), Time in Days (T_DAYS), and Tissue Concentration (CONC_TIS) for Hypothetical 28-Day Bioaccumulation Laboratory Test Data

---- Treatment Level=Station C Sediment Concentration=44 Time (days)=2 -----

Replicate Number	Tissue Concentration
1	0.745
2	1.703
3	2.045
4	1.855
5	1.135

---- Treatment Level=Station C Sediment Concentration=44 Time (days)=4 -----

Replicate Number	Tissue Concentration
1	1.316
2	0.930
3	2.141
4	1.150
5	1.621

---- Treatment Level=Station C Sediment Concentration=44 Time (days)=7 -----

Replicate Number	Tissue Concentration
1	1.583
2	2.715
3	1.016
4	2.221
5	2.134

---- Treatment Level=Station C Sediment Concentration=44 Time (days)=10 ----

Replicate Number	Tissue Concentration
1	1.578
2	2.268
3	1.756
4	2.899
5	0.890

(continued)

Figure 13-12. Example Data Listing from SAS/PC Program Showing Sediment Concentration (CONC_SED), *(continued)* Treatment Level (TRTMNT), Time in Days (T_DAYS), and Tissue Concentration (CONC_TIS) for Hypothetical 28-Day Bioaccumulation Laboratory Test Data

--- Treatment Level=Station C   Sediment Concentration=44   Time (days)=18 ----

Replicate Number	Tissue Concentration
1	2.822
2	2.607
3	3.414
4	1.319
5	1.866

--- Treatment Level=Station C   Sediment Concentration=44   Time (days)=28 ----

Replicate Number	Tissue Concentration
1	1.295
2	2.964
3	2.109
4	2.820
5	3.325

--- Treatment Level=Reference   Sediment Concentration=0.45   Time (days)=2 ----

Replicate Number	Tissue Concentration
1	0.054
2	0.163
3	0.391
4	0.734
5	0.634

--- Treatment Level=Reference   Sediment Concentration=0.45   Time (days)=4 ----

Replicate Number	Tissue Concentration
1	0.441
2	0.797
3	0.203
4	0.564
5	0.018

(continued)

Figure 13-12. Example Data Listing from SAS/PC Program Showing Sediment Concentration (CONC_SED), *(continued)* Treatment Level (TRTMNT), Time in Days (T_DAYS), and Tissue Concentration (CONC_TIS) for Hypothetical 28-Day Bioaccumulation Laboratory Test Data

--- Treatment Level=Reference Sediment Concentration=0.45 Time (days)=7 ----

Replicate Number	Tissue Concentration
1	0.687
2	0.177
3	0.862
4	0.413
5	0.029

--- Treatment Level=Reference Sediment Concentration=0.45 Time (days)=10 ---

Replicate Number	Tissue Concentration
1	0.037
2	0.549
3	0.884
4	0.787
5	0.294

--- Treatment Level=Reference Sediment Concentration=0.45 Time (days)=18 ---

Replicate Number	Tissue Concentration
1	0.856
2	0.598
3	0.016
4	0.806
5	0.119

--- Treatment Level=Reference Sediment Concentration=0.45 Time (days)=28 ---

Replicate Number	Tissue Concentration
1	0.514
2	0.839
3	0.793
4	0.099
5	0.226

Figure 13-12. Example Data Listing from SAS/PC Program Showing Sediment Concentration (CONC_SED), *(continued)* Treatment Level (TRTMNT), Time in Days (T_DAYS), and Tissue Concentration (CONC_TIS) for Hypothetical 28-Day Bioaccumulation Laboratory Test Data

Fitting of Kinetic Model to the Bioaccumulation Data

------------------------ Treatment Level=Reference --------------------------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	6.887855
1	0.685462	1.283176	4.167862
2	0.974848	0.687322	3.452842
3	0.785682	0.730668	2.755431
4	0.802025	0.761427	2.753115
5	0.811932	0.772154	2.753084
6	0.815045	0.775362	2.753082
7	0.815940	0.776284	2.753082
8	0.816195	0.776546	2.753082

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	6.1793341786	3.0896670893
Residual	28	2.7530818214	0.0983243508
Uncorrected Total	30	8.9324160000	
(Corrected Total)	29	2.7815808000	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.8161949523	0.72854762039	-.67615585015	2.3085457547
K2	0.7765458839	0.74248899959	-.74436232210	2.2974540900

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9899643378
K2	0.9899643378	1

Figure 13-13. Example Results from SAS/PC Program Showing Nonlinear Regression Analysis for Reference Treatment Level from 28-Day Bioaccumulation Test

Fitting of Kinetic Model to the Bioaccumulation Data

------------------------- Treatment Level=Station A --------------------------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS   Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	4.511244
1	0.032072	0.283014	3.513831
2	0.032303	0.157206	3.041152
3	0.029106	0.164033	2.856415
4	0.029372	0.167118	2.856061
5	0.029488	0.168038	2.856044
6	0.029522	0.168305	2.856043
7	0.029532	0.168382	2.856043
8	0.029534	0.168404	2.856043

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	8.249353153	4.124676577
Residual	28	2.856042847	0.102001530
Uncorrected Total	30	11.105396000	
(Corrected Total)	29	3.377693467	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.0295344074	0.01095794141	0.00708825264	0.05198056222
K2	0.1684037645	0.08228376939	-.00014561487	0.33695314391

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9540322074
K2	0.9540322074	1

Figure 13-14. Example Results from SAS/PC Program Showing Nonlinear Regression Analysis for Treatment Level A from 28-Day Bioaccumulation Test

Fitting of Kinetic Model to the Bioaccumulation Data

------------------------ Treatment Level=Station B --------------------------

Non-Linear Least Squares Iterative Phase
Dependent Variable CONC_TIS Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	717.141922
1	0.010591	0.448632	10.506473
2	0.013544	0.250922	4.997893
3	0.010636	0.240108	2.892513
4	0.010558	0.235466	2.888916
5	0.010522	0.234465	2.888869
6	0.010514	0.234235	2.888867
7	0.010512	0.234181	2.888867
8	0.010512	0.234169	2.888867

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	43.269707380	21.634853690
Residual	28	2.888866620	0.103173808
Uncorrected Total	30	46.158574000	
(Corrected Total)	29	4.913541467	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.0105115591	0.00190839085	0.00660242738	0.01442069084
K2	0.2341690260	0.05242599994	0.12678004972	0.34155800218

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9631505062
K2	0.9631505062	1

Figure 13-15. Example Results from SAS-PC Program Showing Nonlinear Regression Analysis for Treatment Level B from 28-Day Bioaccumulation Test

Fitting of Kinetic Model to the Bioaccumulation Data

------------------------ Treatment Level=Station C --------------------------

Non-Linear Least Squares Iterative Phase

Dependent Variable CONC_TIS   Method: Marquardt

Iter	K1	K2	Sum of Squares
0	0.100000	0.500000	1140.757812
1	0.018864	0.469373	17.310419
2	0.018651	0.346647	13.626377
3	0.017109	0.332666	13.307998
4	0.016865	0.326231	13.305115
5	0.016748	0.323514	13.304649
6	0.016698	0.322342	13.304561
7	0.016676	0.321833	13.304544
8	0.016667	0.321611	13.304541
9	0.016662	0.321515	13.304541
10	0.016661	0.321472	13.304541

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CONC_TIS

Source	DF	Sum of Squares	Mean Square
Regression	2	116.05813143	58.02906572
Residual	28	13.30454057	0.47516216
Uncorrected Total	30	129.36267200	
(Corrected Total)	29	16.29165320	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
K1	0.0166606579	0.00451591707	0.00741029143	0.02591102431
K2	0.3214724020	0.10238980337	0.11173799211	0.53120681186

Asymptotic Correlation Matrix

Corr	K1	K2
K1	1	0.9717375672
K2	0.9717375672	1

Figure 13-16. Example Results from SAS/PC Program Showing Nonlinear Regression Analysis for Treatment Level C from 28-Day Bioaccumulation Test

Listing of Predicted Tissue Concentrations and One-Sided 95% Confidence Intervals, Based on the Fitted Kinetic Model

------------ Treatment Level=Station A Sediment Concentration=4 ------------

Time (days)	Predicted Concentration	Lower 95% Conf. Bound on the Concentration	Upper 95% Conf. Bound on the Concentration
2	0.2006	0.0990	0.3022
4	0.3438	0.2060	0.4817
7	0.4857	0.3497	0.6217
10	0.5713	0.4516	0.6910
18	0.6677	0.5244	0.8109
28	0.6952	0.5070	0.8834
999	0.7015	0.4931	0.9099

----------- Treatment Level=Station B Sediment Concentration=33 ------------

Time (days)	Predicted Concentration	Lower 95% Conf. Bound on the Concentration	Upper 95% Conf. Bound on the Concentration
2	0.5540	0.4262	0.6817
4	0.9008	0.7490	1.0525
7	1.1937	1.0663	1.3211
10	1.3389	1.2266	1.4512
18	1.4594	1.3105	1.6084
28	1.4792	1.3088	1.6496
999	1.4813	1.3070	1.6557

----------- Treatment Level=Station C Sediment Concentration=44 ------------

Time (days)	Predicted Concentration	Lower 95% Conf. Bound on the Concentration	Upper 95% Conf. Bound on the Concentration
2	1.0815	0.7440	1.4189
4	1.6500	1.3136	1.9864
7	2.0401	1.7958	2.2843
10	2.1888	1.9462	2.4313
18	2.2734	1.9606	2.5861
28	2.2801	1.9534	2.6067
999	2.2803	1.9528	2.6079

(continued)

Figure 13-17. Example Results from SAS/PC Program Showing Data Listing of Nonlinear Regression Analysis Results for 28-Day Bioaccumulation Test. Output Includes Predicted Tissue Concentration, i.e., Bioaccumulation (PRED_CT), and Upper (UP_CL) and Lower (LOW_CL) 95% Confidence Bounds on the Observation

---------- Treatment Level=Reference   Sediment Concentration=0.45 -----------

Time (days)	Predicted Concentration	Lower 95% Conf. Bound on the Concentration	Upper 95% Conf. Bound on the Concentration
2	0.3729	0.1511	0.5947
4	0.4518	0.3421	0.5615
7	0.4709	0.3623	0.5795
10	0.4728	0.3570	0.5885
18	0.4730	0.3559	0.5900
28	0.4730	0.3559	0.5900
999	0.4730	0.3559	0.5900

Figure 13-17. *(continued)* Example Results from SAS/PC Program Showing Data Listing of Nonlinear Regression Analysis Results for 28-Day Bioaccumulation Test. Output Includes Predicted Tissue Concentration, i.e., Bioaccumulation (PRED_CT), and Upper (UP_CL) and Lower (LOW_CL) 95% Confidence Bounds on the Observation

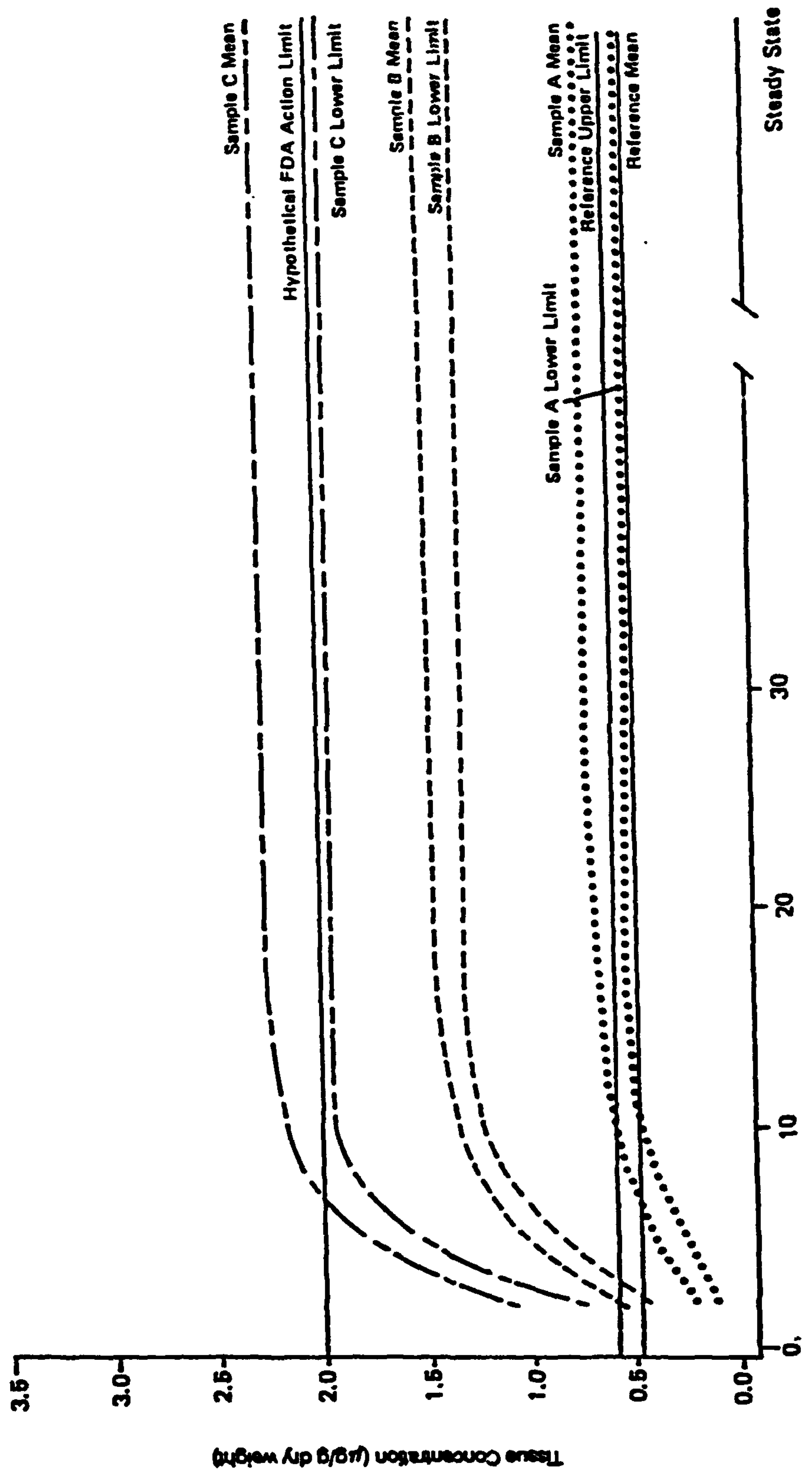

Figure 13-18. Nonlinear Regression Analysis Lines with 95% One-Sided Confidence Bounds on Bioaccumulation Data

The mean tissue concentration at steady state for dredged-material sample B is less than the FDA action levels. Steady-state bioaccumulation in sample B is statistically greater than steady-state bioaccumulation in the reference sediment because there is no overlap of confidence levels. The predicted steady-state tissue concentration in dredged-material sample C is not statistically different from the FDA action level, as demonstrated by the lower 95% one-sided confidence bound being lower than the action level.

Compliance with the regulations is determined in accordance with the Tier IV bioaccumulation guidance in Section 7.2.

13.3.3 Steady-State Bioaccumulation from Field Data

The field bioaccumulation test is designed to show differences, if any, between organisms living at the proposed disposal site and organisms living in the sediments in the reference area. This approach is valid only under the conditions described in Section 12.2.2.

The mean tissue concentration in field organisms collected at the disposal site is calculated along with lower 95% one-sided confidence levels using the formulas given in Section 13.3.1. This mean and confidence level are compared to the mean and upper 95% one-sided confidence level calculated at steady state for organisms collected from the reference area. Bioaccumulation in two groups of organisms is considered to be statistically different if the 95%, one-sided confidence intervals do not overlap.

Compliance with the regulations is determined in accordance with Tier IV bioaccumulation guidance in Section 7.2.

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14.0 QUALITY-ASSURANCE CONSIDERATIONS

The purpose of a quality-assurance (QA) program in a dredging study is to ensure that the data produced by the study are of known and documented quality. This is accomplished by ensuring that proper quality-control (QC) procedures are built into the study at the beginning and by verifying that the procedures are followed during the study.

The distinction between QA and QC is that the former is a management tool and the latter is a series of procedures designed to implement that tool by measuring precision, accuracy, comparability, completeness, and representativeness. QA activities ensure that QC procedures have been implemented and documented. QA reports to upper management and operates independently of activities involved with conduct of the tests. QC operates as an integral part of the study and includes measurements of data quality, using blanks, spikes, and control test groups to which test results can be compared.

A complete QA effort in a dredging study has two components: a QA program implemented by the responsible governmental agency (the data user) and QA programs implemented by the laboratories performing the tests (the data generators).

14.1 STRUCTURE OF QA PROGRAMS

The organization of the QA effort for a dredging study and the responsibilities of each component are discussed in this section.

14.1.1 Government (Data User) QA Program

The function of the government QA program is to ensure that laboratories contracted for the dredging studies comply with the procedures in this manual or with other specified guidelines. Oversight of the QA effort for a dredging study should be the responsibility of a QA Coordinator to be established in the USACE District Office, working in conjunction with the EPA Regional QA Officer. District QA Coordinators should be responsible for ensuring that data submitted with permit applications and laboratories under contract to their Districts comply with the QA needs of the regulations and guidelines governing dredged-material studies. This responsibility should be carried out in three ways: preaward inspections, interlaboratory comparisons, and routine inspections during conduct of the studies. Data-quality objectives

should be established for testing. The QA program should be designed with the assistance of administrative and scientific expertise from Headquarters of EPA and the USACE, and other qualified sources as appropriate. Some QA considerations in contractor selection are discussed by Sturgis (1990).

14.1.1.1 Preaward Inspections

Before a government contract is awarded, it is strongly recommended that the District QA Coordinator inspect the laboratories seeking to work on the study. This preaward inspection assesses the laboratory's capabilities, personnel, and equipment. It establishes the groundwork necessary to ensure that tests will be conducted properly, provides the initial contact between government and laboratory staff, and emphasizes the importance that the government places on quality assurance.

This inspection is designed to establish that the laboratory has implemented the following measures

- An independent QA program
- Written work plans for each test
- Technically sound written standard operating procedures (SOP) for all study activities.

14.1.1.2 Interlaboratory Comparison

In dredging studies it is important for data collected and processed at various laboratories to be comparable. To ensure this comparability, proficiency testing of a laboratory is recommended before a contract is signed and yearly thereafter. Each laboratory taking part in a proficiency test analyzes samples, prepared to a known concentration, of a standard from the National Institute for Standards and Technology (NIST) or other recognized source of standard reference material (SRM) (refer to Table 9-4 for sources of SRMs). Results are compared with predetermined criteria of acceptability. Proficiency testing programs already established by either EPA or the USACE may be used, or a program may be designed specifically for dredging evaluations.

14.1.1.3 Routine Inspections

The purpose of routine surveillance inspections during conduct of contract work is to ensure that laboratories are complying with the QA Plan. It is suggested that the District QA Coordinator develop checklists for review of training records, equipment specifications, QC procedures for analytical tasks, management organization, etc. The QA Coordinator should also establish laboratory review files for quick assessment of the laboratory's activity on a study, and to aid in monitoring the overall quality of the laboratory. Procedures for inspections by the District QA Coordinator are similar to systems audits (Section 14.3.4) conducted by the laboratories themselves.

14.1.2 Data Generator QA Program

Ideally, each laboratory participating in a dredged-material study should have a written QA Program Plan that describes the organization's QA program, including its policies, areas of application, and authorities. Individuals involved in the QA program should be identified and their responsibilities clearly stated. For any given study, QA personnel should be entirely independent of the technical personnel engaged in the study to ensure unbiased assessments of the work performed.

Where possible, the laboratory should have a QA Manager or Coordinator who is responsible for the development, implementation, and administration of the QA program. For dredging studies, the QA Manager/Coordinator should ensure that the appropriate QA planning documents exist for each study (Section 14.2.8); routine procedures that impact data quality are described in SOPs; sufficiently detailed audits are conducted at intervals frequent enough to ensure conformance with approved study plans and SOPs and to identify deficiencies; and appropriate corrective actions are implemented in a timely manner.

14.2 GENERAL COMPONENTS OF ALL QA PROGRAMS

A well-structured QA program defines the criteria that the data must meet to be acceptable. The procedures for collecting and analyzing those data should be an integral part of the overall study plan. A good QA program sets standards for personnel qualifications, facilities, equipment, services, data generation, recordkeeping, and data-quality assessments.

14.2.1 Organization

The QA program plan should describe the lines of authority and responsibilities for technical personnel, including those responsible for quality assurance. Procedures should be in place for describing the qualifications, training, job descriptions, etc., for all field and laboratory personnel.

14.2.2 Personnel Qualifications

All personnel performing tasks and functions related to data quality have to be appropriately qualified and adequately trained. It is generally the responsibility of the contractor's QA staff to ensure that personnel are qualified and trained. Records of qualifications and training of personnel should be kept current so that training can be verified by internal QA personnel or by EPA and the USACE.

14.2.3 Facilities

The QA program plan should provide a description of the physical layout of the laboratory, define space for each area of testing, describe traffic-flow patterns, and document special laboratory needs.

14.2.4 Equipment and Supplies

The QA program plan should describe how field and laboratory equipment essential to the performance of environmental measurements will be maintained in proper working order. This is demonstrated through records that document the reliability and performance characteristics of the equipment. Such equipment should be subject to regular inspection and preventive-maintenance procedures to ensure proper working order. Instruments should have periodic calibration and preventive maintenance performed by qualified technical personnel, and a permanent record kept of calibrations, problems diagnosed, and corrective actions applied. An acceptance testing program for key materials used in the performance of environmental measurements (chemical and biological materials) should be applied prior to their use.

14.2.5 Test Methods and Procedures

All methods and procedures used in the field and laboratory should be in written form, authorized, and readily available to all personnel. There should be a mechanism to describe the circumstances under which nonstandard methods or procedures may be used, and the appropriate approval and documentation should be described.

14.2.6 Sample Handling and Tracking

Sample custody is a part of any good field or laboratory operation. Where samples may be needed for potential litigation, chain-of-custody procedures should be used. Sample custody is important for both parts of the dredged-material evaluation process -- the field (sample collection) and the laboratory (receipt, analysis and reporting). More detailed sample-handling guidance is provided in Sections 8.2.6 through 8.2.8.

14.2.7 Documentation and Recordkeeping

Records should be maintained to ensure that all aspects of the field and laboratory work are documented. It is important to record all the events that are associated with a sample so that the scope and validity of the resulting data may be properly interpreted. A document trail is generated to show the course of the sample from the field through the laboratory.

All data should be recorded directly, promptly, legibly, and indelibly, so that data are easily traceable. Data entries should be dated on the date of entry and signed or initialed by the person making the measurement and the person entering the data. Changes on entries should be made so as not to obscure the original entry, and should indicate the reason for the change, the person making the change, and the date of change. In computer-driven data-collection systems, the person responsible for direct data input should be identified at the time of input.

14.2.8 Quality-Assurance Plan

It is good practice for the government to require that QA study plans be developed by the contractor for all dredged-material evaluations. These study plans may be developed in accordance with either EPA (1984) or the USACE (1985). EPA (1987) contains QA guidance that is generally applicable to sample collection and laboratory aspects of dredged-material

evaluations and should be considered in QA study-plan development. Topics covered in these documents include provisions for (1) name of the study, (2) name of requesting agency, (3) date of the request, (4) date of initiation, (5) program officer, (6) QA officer, (7) study description, (8) fiscal information, (9) schedule of tasks and products, (10) organization and responsibilities, (11) data- quality requirements and assessments, (12) sampling and analytical procedures, (13) sample- custody procedures, (14) equipment calibration and maintenance procedures, (15) documentation, data reduction, and reporting, (16) data validation, (17) performance and systems audits, (18) corrective action, and (19) reports.

QA study plans are valuable documents because they provide in one place an overall plan for conducting work, including standards of data quality that have to be maintained. QA study plans are particularly useful for work that involves many people or that lasts over a long period. When many people are involved, the plan ensures that everyone has a thorough understanding of the goals and procedures of the program. When work is conducted over a long period, the plan provides a basis of continuity, ensuring that procedures do not slowly change over time without the persons involved in the program evaluating the nature of the changes and their possible impact on data quality.

14.2.9 Standard Operating Procedures (SOP)

Standard operating procedures (SOP) are documents describing routine study methods and procedures that affect data quality and integrity. Like QA study plans, SOPs ensure that all persons conducting work are following the same procedures and that the procedures do not change over time. SOPs should be prepared for use of equipment and facilities, measurements, and other aspects of work that impact data quality.

14.3 DATA-QUALITY ASSESSMENT

14.3.1 Data Validation

Data validation involves all procedures used to accept or reject data after collection and prior to use, including editing, screening, checking, auditing, verifying, and reviewing. Data-validation procedures ensure that the standards for data accuracy and precision were met, that data were generated in accordance with the QA study plan and SOPs, and that data are

traceable and defensible. It is important for all reported data to be properly validated following standardized procedures to ensure that data are of consistent and documented quality.

14.3.2 Chemical Quality Control

Chemical QC specifications are the ranges considered acceptable for instrument calibration, analyte recovery, data accuracy, and data precision. Instrument calibration involves determining a linear response over the range of data to be collected. Recovery is determined by analyzing a sample spiked with a known amount of chemical. Procedural accuracy is established by including a series of spiked and blank samples in each analysis. Precision is established by analyzing replicate samples. QC procedures are discussed in more detail for sediment, water, and tissue analyses in Sections 9.3.3, 9.4.3, and 9.5.3, respectively.

The USACE District QA Coordinator or management authority for the program may require that certain samples be submitted on a routine basis to government laboratories for analysis, and EPA or the USACE may participate in some studies. These activities provide an independent quality assurance check on activities being performed and on data being generated.

14.3.3 Biological Quality Control (Reference-Toxicant Testing)

Biological QC involves periodic reference-toxicant tests conducted with all stocks of organisms to be used in the dredged-material tests to determine the relative health of the test organisms. The application and benefits of reference-toxicant tests are discussed by Lee (1980). Detailed assistance in establishing a biological QC program can be provided by scientists from Headquarters of EPA and the USACE. When sufficient reference-toxicant data have been generated for a particular species, it may be possible to stipulate an acceptable LC_{50} range for that species with the reference toxicant.

14.3.4 Performance and System Audits

Performance and system audits are an essential part of the field and laboratory QA program. A performance audit independently collects measurement data using performance evaluation (PE) samples, field blanks, trip blanks, duplicate samples, and spiked samples. A systems audit consists of a review of the total data production process that includes on-site

reviews of field and laboratory operational systems. The purpose of these inspections is to verify that (1) appropriate SOPs are in place, (2) training of the staff is appropriate and documented, (3) all equipment is properly calibrated and maintained, (4) approved analytical procedures are being followed, and (5) all aspects of the study are on schedule.

14.3.5 Management of Nonconformance Events

One purpose of any QA program is to identify a nonconformance event as quickly as possible. A nonconformance event is defined as any event that does not follow defined methods, procedures, protocols, or any occurrence that may affect the quality of the data or study. A QA program should have a corrective action plan to provide feedback channels to the appropriate management authority defining how all nonconformance events were corrected.

14.3.6 Archiving of Data and Samples

A procedure should be established for the retention of all appropriate field and laboratory records, specimens, and samples as various tasks or phases are completed. The archiving procedure should indicate the storage requirements, location, indexing codes, retention time, security, and environmental measures needed to preserve the data and samples.

14.4 REFERENCES

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Appendix A

TITLE 40, CODE OF FEDERAL REGULATIONS, PARTS 220-228

SUBCHAPTER H—OCEAN DUMPING

PART 220—GENERAL

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2468, Jan. 11, 1977, unless otherwise noted.

§ 220.1 Purpose and scope.

(a) *General.* This Subchapter H establishes procedures and criteria for the issuance of permits by EPA pursuant to section 102 of the Act. This Subchapter H also establishes the criteria to be applied by the Corps of Engineers in its review of activities involving the transportation of dredged material for the purpose of dumping it in ocean waters pursuant to section 103 of the Act. Except as may be authorized by a permit issued pursuant to this Subchapter H, or pursuant to section 103 of the Act, and subject to other applicable regulations promulgated pursuant to section 108 of the Act:

(1) No person shall transport from the United States any material for the purpose of dumping it into ocean waters;

(2) In the case of a vessel or aircraft registered in the United States or flying the United States flag or in the case of a United States department, agency, or instrumentality, no person shall transport from any location any material for the purpose of dumping it into ocean waters; and

(3) No person shall dump any material transported from a location outside the United States:

(i) Into the territorial sea of the United States; or

(ii) Into a zone contiguous to the territorial sea of the United States, extending to a line twelve nautical miles seaward from the base line from which the breadth of the territorial sea is measured, to the extent that it may affect the territorial sea or the territory of the United States.

(b) *Relationship to international agreements.* In accordance with section 102(a) of the Act, the regulations and criteria included in this Subchapter H apply the standards and criteria binding upon the United States under the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter to the extent that application of such standards and criteria do not relax the requirements of the Act.

(c) *Exclusions*—(1) *Fish wastes.* This Subchapter H does not apply to, and no permit hereunder shall be required for, the transportation for the purpose of dumping or the dumping in ocean waters of fish wastes unless such dumping occurs in:

(i) Harbors or other protected or enclosed coastal waters; or

(ii) Any other location where the Administrator finds that such dumping may reasonably be anticipated to endanger health, the environment or ecological systems.

(2) *Fisheries resources.* This Subchapter H does not apply to, and no permit hereunder shall be required for, the placement or deposit of oyster shells or other materials for the purpose of developing, maintaining or harvesting fisheries resources; provided, such placement or deposit is regulated under or is a part of an authorized State or Federal program certified to EPA by the agency authorized to enforce the regulation, or to administer the program, as the case may be; and provided further, that the National Oceanic and Atmospheric Administration, the U.S. Coast Guard, and the U.S. Army Corps of Engineers concur in such placement or deposit as it may affect their responsibilities and such concurrence is evidenced by letters of concurrence from these agencies.

(3) *Vessel propulsion and fixed structures.* This Subchapter H does not apply to, and no permit hereunder shall be required for:

(i) Routine discharges of effluent incidental to the propulsion of vessels or the operation of motor-driven equipment on vessels; or

(ii) Construction of any fixed structure or artificial island, or the intentional placement of any device in

ocean waters or on or in the submerged land beneath such waters, for a purpose other than disposal when such construction or such placement is otherwise regulated by Federal or State law or made pursuant to an authorized Federal or State program certified to EPA by the agency authorized to enforce the regulations or to administer the program, as the case may be.

(4) *Emergency to safeguard life at sea.* This Subchapter H does not apply to, and no permit hereunder shall be required for, the dumping of material into ocean waters from a vessel or aircraft in an emergency to safeguard life at sea to the extent that the person owning or operating such vessel or aircraft files timely reports required by § 224.2(b).

§ 220.2 Definitions.

As used in this Subchapter H:

(a) "Act" means the Marine Protection, Research, and Sanctuaries Act of 1972, as amended (33 U.S.C. 1401);

(b) "FWPCA" means the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251);

(c) "Ocean" or "ocean waters" means those waters of the open seas lying seaward of the baseline from which the territorial sea is measured, as provided for in the Convention on the Territorial Sea and the Contiguous Zone (15 UST 1606; TIAS 5639); this definition includes the waters of the territorial sea, the contiguous zone and the oceans as defined in section 502 of the FWPCA.

(d) "Material" means matter of any kind or description, including, but not limited to, dredged material, solid waste, incinerator residue, garbage, sewage, sewage sludge, munitions, radiological, chemical, and biological warfare agents, radioactive materials, chemicals, biological and laboratory waste, wreck or discarded equipment, rock, sand, excavation debris, industrial, municipal, agricultural, and other waste, but such term does not mean sewage from vessels within the meaning of section 312 of the FWPCA. Oil within the meaning of section 311 of the FWPCA shall constitute "material" for purposes of this Subchapter H only to the extent that it is taken on board a vessel or aircraft for the primary purpose of dumping.

(e) "Dumping" means a disposition of material: *Provided,* That it does not mean a disposition of any effluent from any outfall structure to the extent that such disposition is regulated under the provisions of the FWPCA, under the provisions of section 13 of the River and Harbor Act of 1899, as amended (33 U.S.C. 407), or under the provisions of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2011), nor does it mean a routine discharge of effluent incidental to the propulsion of, or operation of motor-driven equipment on, vessels: *Provided further,* That it does not mean the construction of any fixed structure or artificial island nor the intentional placement of any device in ocean waters or on or in the submerged land beneath such waters, for a purpose other than disposal, when such construction or such placement is otherwise regulated by Federal or State law or occurs pursuant to an authorized Federal or State program: And provided further, That it does not include the deposit of oyster shells, or other materials when such deposit is made for the purpose of developing, maintaining, or harvesting fisheries resources and is otherwise regulated by Federal or State law or occurs pursuant to an authorized Federal or State program.

(f) "Sewage Treatment Works" means municipal or domestic waste treatment facilities of any type which are publicly owned or regulated to the extent that feasible compliance schedules are determined by the availability of funding provided by Federal, State, or local governments.

(g) "Criteria" means the criteria set forth in Part 227 of this Subchapter H.

(h) "Dredged Material Permit" means a permit issued by the Corps of Engineers under section 103 of the Act (see 33 CFR 209.120) and any Federal projects reviewed under section 103(e) of the Act (see 33 CFR 209.145).

(i) Unless the context otherwise requires, all other terms shall have the meanings assigned to them by the Act.

§ 220.3 Categories of permits.

This § 220.3 provides for the issuance of general, special, emergency, interim and research permits for ocean dumping under section 102 of the Act.

(a) *General permits.* General permits may be issued for the dumping of certain materials which will have a minimal adverse environmental impact and are generally disposed of in small quantities, or for specific classes of materials that must be disposed of in emergency situations. General permits may be issued on application of an interested person in accordance with the procedures of Part 221 or may be issued without such application whenever the Administrator determines that issuance of a general permit is necessary or appropriate.

(b) *Special permits.* Special permits may be issued for the dumping of materials which satisfy the Criteria and shall specify an expiration date no later than three years from the date of issue.

(c) *Emergency permits.* For any of the materials listed in § 227.6, except as trace contaminants, after consultation with the Department of State with respect to the need to consult with parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter that are likely to be affected by the dumping, emergency permits may be issued to dump such materials where there is demonstrated to exist an emergency requiring the dumping of such materials, which poses an unacceptable risk relating to human health and admits of no other feasible solution. As used herein, "emergency" refers to situations requiring action with a marked degree of urgency, but is not limited in its application to circumstances requiring immediate action. Emergency permits may be issued for other materials, except those prohibited by § 227.5, without consultation with the Department of State when the Administrator determines that there exists an emergency requiring the dumping of such materials which poses an unacceptable risk to human health and admits of no other feasible solution.

(d) *Interim permits.* Prior to April 23, 1978, interim permits may be issued in accordance with Subpart A of Part 227 to dump materials which are not in compliance with the environmental impact criteria of Subpart B of Part 227, or which would cause substantial adverse effects as determined in accordance with the criteria of Subpart D or E of Part 227 or for which an ocean disposal site has not been designated on other than an interim basis pursuant to Part 228 of this Subchapter H; provided, however, no permit may be issued for the ocean dumping of any materials listed in § 227.5, or for any of the materials listed in § 227.6, except as trace contaminants; provided further that the compliance date of April 23, 1978, does not apply to the dumping of wastes by existing dumpers when the Regional Administrator determines that the permittee has exercised his best efforts to comply with all requirements of a special permit by April 23, 1978, and has an implementation schedule adequate to allow phasing out of ocean dumping or compliance with all requirements necessary to receive a special permit by December 31, 1981, at the latest. No interim permit will be granted for the dumping of waste from a facility which has not previously dumped wastes in the ocean from a new facility, or for the dumping of an increased amount of waste from the expansion or modification of an existing facility, after the effective date of these regulations (except when the facility is operated by a municipality now dumping such wastes). No interim permit will be issued for the dumping of any material in the ocean for which an interim permit had previously been issued unless the applicant demonstrates that he has exercised his best efforts to comply with all provisions of the previously issued permits. Interim permits shall specify an expiration date no later than one year from the date of issue.

(e) *Research permits.* Research permits may be issued for the dumping of any materials, other than materials specified in § 227.5 or for any of the materials listed in § 227.6 except as trace contaminants, unless subject to the exclusion of § 227.6(g), into the ocean as part of a research project when it is determined that the scien-

tific merit of the proposed project outweighs the potential environmental or other damage that may result from the dumping. Research permits shall specify an expiration date no later than 18 months from the date of issue.

(f) *Permits for incineration at sea.* Permits for incineration of wastes at sea will be issued only as research permits or as interim permits until specific criteria to regulate this type of disposal are promulgated, except in those cases where studies on the waste, the incineration method and vessel, and the site have been conducted and the site has been designated for incineration at sea in accordance with the procedures of § 228.4(b). In all other respects the requirements of Parts 220 through 228 apply.

[42 FR 2468, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 220.4 Authorities to issue permits.

(a) *Determination by Administrator.* The Administrator, or such other EPA employee as he may from time to time designate in writing, shall issue, deny, modify, revoke, suspend, impose conditions on, initiate and carry out enforcement activities and take any and all other actions necessary or proper and permitted by law with respect to general, special, emergency, interim, or research permits.

(b) *Authority delegated to Regional Administrators.* Regional Administrators, or such other EPA employees as they may from time to time designate in writing, are delegated the authority to issue, deny, modify, revoke, suspend, impose conditions on, initiate and carry out enforcement activities, and take any and all other actions necessary or proper and permitted by law with respect to special and interim permits for:

(1) The dumping of material in those portions of the territorial sea which are subject to the jurisdiction of any State within their respective Regions, and in those portions of the contiguous zone immediately adjacent to such parts of the territorial sea; and in the oceans with respect to approved waste disposal sites designated pursuant to Part 228 of this Subchapter H, and

(2) Where transportation for dumping is to originate in one Region and dumping is to occur at a location within another Region's jurisdiction conferred by order of the Administrator, the Region in which transportation is to originate shall be responsible for review of the application and shall prepare the technical evaluation of the need for dumping and alternatives to ocean dumping. The Region having jurisdiction over the proposed dump site shall take all other actions required by this Subchapter H with respect to the permit application, including without limitation, determining to issue or deny the permit, specifying the conditions to be imposed, and giving public notice. If both Regions do not concur in the disposition of the permit application, the Administrator will make the final decision on all issues with respect to the permit application, including without limitation, issuance or denial of the permit and the conditions to be imposed.

(c) *Review of Corps of Engineers Dredged Material Permits.* Regional Administrators have the authority to review, to approve or to disapprove or to propose conditions upon Dredged Material Permits for ocean dumping of dredged material at locations within the respective Regional jurisdictions. Regional jurisdiction to act under this paragraph (c) of § 220.4 is determined by the Administrator in accordance with § 228.4(e).

PART 221—APPLICATIONS FOR OCEAN DUMPING PERMITS UNDER SECTION 102 OF THE ACT

Sec.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2470, Jan. 11, 1977, unless otherwise noted.

§ 221.1 Applications for permits.

Applications for general, special, emergency, interim and research permits under section 102 of the Act may

be filed with the Administrator or the appropriate Regional Administrator, as the case may be, authorized by § 220.4 to act on the application. Applications shall be made in writing and shall contain, in addition to any other material which may be required, the following:

(a) Name and address of applicant;

(b) Name of the person or firm transporting the material for dumping, the name of the person(s) or firm(s) producing or processing all materials to be transported for dumping, and the name or other identification, and usual location, of the conveyance to be used in the transportation and dumping of the material to be dumped, including information on the transporting vessel's communications and navigation equipment;

(c) Adequate physical and chemical description of material to be dumped, including results of tests necessary to apply the Criteria, and the number, size, and physical configuration of any containers to be dumped;

(d) Quantity of material to be dumped;

(e) Proposed dates and times of disposal;

(f) Proposed dump site, and in the event such proposed dump site is not a dump site designated in this Subchapter H, detailed physical, chemical and biological information relating to the proposed dump site and sufficient to support its designation as a site according to the procedures of Part 228 of this Subchapter H;

(g) Proposed method of releasing the material at the dump site and means by which the disposal rate can be controlled and modified as required;

(h) Identification of the specific process or activity giving rise to the production of the material;

(i) Description of the manner in which the type of material proposed to be dumped has been previously disposed of by or on behalf of the person(s) or firm(s) producing such material;

(j) A statement of the need for the proposed dumping and an evaluation of short and long term alternative means of disposal, treatment or recycle of the material. Means of disposal shall include without limitation, landfill, well injection, incineration, spread of material over open ground; biological, chemical or physical treatment; recovery and recycle of material within the plant or at other plants which may use the material, and storage. The statement shall also include an analysis of the availability and environmental impact of such alternatives; and

(k) An assessment of the anticipated environmental impact of the proposed dumping, including without limitation, the relative duration of the effect of the proposed dumping on the marine environment, navigation, living and non-living marine resource exploitation, scientific study, recreation and other uses of the ocean.

§ 221.2 Other information.

In the event the Administrator, Regional Administrator, or a person designated by either to review permit applications, determines that additional information is needed in order to apply the Criteria, he shall so advise the applicant in writing. All additional information requested pursuant to this § 221.2 shall be deemed part of the application and for purposes of applying the time limitation of § 222.1, the application will not be considered complete until such information has been filed.

§ 221.3 Applicant.

Any person may apply for a permit under this Subchapter H even though the proposed dumping may be carried on by a permittee who is not the applicant; provided however, that the Administrator or the Regional Administrator, as the case may be, may, in his discretion, require that an application be filed by the person or firm producing or processing the material proposed to be dumped. Issuance of a permit will not excuse the permittee from any civil or criminal liability which may attach by virtue of his having transported or dumped materials in violation of the terms or conditions of a permit, notwithstanding that the permittee may not have been the applicant.

§ 221.4 Adequacy of information in application.

No permit issued under this Subchapter H will be valid for the transportation or dumping of any material which is not accurately and adequately described in the application. No permittee shall be relieved of any liability which may arise as a result of the transportation or dumping of material which does not conform to information provided in the application solely by virtue of the fact that such information was furnished by an applicant other than the permittee.

§ 221.5 Processing fees.

(a) A processing fee of $1,000 will be charged in connection with each application for a permit for dumping in an existing dump site designated in this Subchapter H.

(b) A processing fee of an additional $3,000 will be charged in connection with each application for a permit for dumping in a dump site other than a dump site designated in this Subchapter H.

(c) Notwithstanding any other provision of this § 221.5, no agency or instrumentality of the United States or of a State or local government will be required to pay the processing fees specified in paragraphs (a) and (b) of this section.

PART 222—ACTION ON OCEAN DUMPING PERMIT APPLICATIONS UNDER SECTION 102 OF THE ACT

Sec.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2471, Jan. 11, 1977, unless otherwise noted.

§ 222.1 General.

Decisions as to the issuance, denial, or imposition of conditions on general, special, emergency, interim and research permits under section 102 of the Act will be made by application of the criteria of Parts 227 and 228. Final action on any application for a permit will, to the extent practicable, be taken within 180 days from the date a complete application is filed.

§ 222.2 Tentative determinations.

(a) Within 30 days of the receipt of his initial application, an applicant shall be issued notification of whether his application is complete and what, if any, additional information is required. No such notification shall be deemed to foreclose the Administrator or the Regional Administrator, as the case may be, from requiring additional information at any time pursuant to § 221.2.

(b) Within 30 days after receipt of a completed permit application, the Administrator or the Regional Administrator, as the case may be, shall publish notice of such application including a tentative determination with respect to issuance or denial of the permit. If such tentative determination is to issue the permit, the following additional tentative determinations will be made:

(1) Proposed time limitations, if any;

(2) Proposed rate of discharge from the barge or vessel transporting the waste;

(3) Proposed dumping site; and

(4) A brief description of any other proposed conditions determined to be appropriate for inclusion in the permit in question.

§ 222.3 Notice of applications.

(a) *Contents.* Notice of every complete application for a general, special, interim, emergency and research permit shall, in addition to any other material, include the following:

(1) A summary of the information included in the permit application;

(2) Any tentative determinations made pursuant to paragraph (b) of § 222.2;

(3) A brief description of the procedures set forth in § 222.5 for request-

ing a public hearing on the application including specification of the date by which requests for a public hearing must be filed;

(4) A brief statement of the factors considered in reaching the tentative determination with respect to the permit and, in the case of a tentative determination to issue the permit, the reasons for the choice of the particular permit conditions selected; and

(5) The location at which interested persons may obtain further information on the proposed dumping, including copies of any relevant documents.

(b) *Publication*—(1) *Special, interim and research permits.* Notice of every complete application for special, interim and research permits shall be given by:

(i) Publication in a daily newspaper of general circulation in the State in closest proximity to the proposed dump site; and

(ii) Publication in a daily newspaper of general circulation in the city in which is located the office of the Administrator or the Regional Administrator, as the case may be, giving notice of the permit application.

(2) *General permits.* Notice of every complete application for a general permit or notice of action proposed to be taken by the Administrator to issue a general permit, without an application, shall be given by publication in the FEDERAL REGISTER.

(3) *Emergency permits.* Notice of every complete application for an emergency permit shall be given by publication in accordance with paragraphs (b)(1)(i) and (ii) of this section; *Provided, however,* That no such notice and no tentative determination in accordance with § 222.2 shall be required in any case in which the Administrator determines:

(i) That an emergency, as defined in paragraph (c) of § 220.3 exists;

(ii) That the emergency poses an unacceptable risk relating to human health;

(iii) That the emergency admits of no other feasible solution; and

(iv) That the public interest requires the issuance of an emergency permit as soon as possible.

Notice of any determination made by the Administrator pursuant to this paragraph (b)(3) shall be given as soon as practicable after the issuance of the emergency permit by publication in accordance with paragraphs (b)(1)(i) and (ii) and with paragraphs (a), (c) through (i) of this section.

(c) *Copies of notice sent to specific persons.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed by the Administrator or the Regional Administrator, as the case may be, to any person, group or Federal, State or local agency upon request. Any such request may be a standing request for copies of such notices and shall be submitted in writing to the Administrator or to any Regional Administrator and shall relate to all or any class of permit applications which may be acted upon by the Administrator or such Regional Administrator, as the case may be.

(d) *Copies of notice sent to States.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed to the State water pollution control agency and to the State agency responsible for carrying out the Coastal Zone Management Act, if such agency exists, for each coastal State within 500 miles of the proposed dumping site.

(e) *Copies of notice sent to Corps of Engineers.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed to the office of the appropriate District Engineer of the U.S. Army Corps of Engineers for purposes of section 106(c) of the Act, (pertaining to navigation, harbor approaches, and artificial islands on the outer continental shelf).

(f) *Copies of notice sent to Coast Guard.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be sent to the appropriate district office of the U.S. Coast Guard for review and possible suggestion of additional conditions to be included in the permit to facilitate surveillance and enforcement.

(g) *Fish and Wildlife Coordination Act.* The Fish and Wildlife Coordination Act, Reorganization Plan No. 4 of 1970, and the Act require that the Ad-

ministrator or the Regional Administrator, as the case may be, consult with appropriate regional officials of the Departments of Commerce and Interior, the Regional Director of the NMFS-NOAA, and the agency exercising administrative jurisdiction over the fish and wildlife resources of the States subject to any dumping prior to the issuance of a permit under this Subchapter H. Copies of the notice shall be sent to the persons noted in paragraph (g) of this section.

(h) *Copies of notice sent to Food and Drug Administration.* In addition to the publication of notice required by paragraph (b) of this section, copies of such notice will be mailed to Food and Drug Administration, Shellfish Sanitation Branch (HF-417), 200 C Street SW., Washington, DC 20204.

(i) *Failure to give certain notices.* Failure to send copies of any public notice in accordance with paragraphs (c) through (h) of this section shall not invalidate any notice given pursuant to this section nor shall such failure invalidate any subsequent administrative proceeding.

(j) *Failure of consulted agency to respond.* Unless advice to the contrary is received from the appropriate Federal or State agency within 30 days of the date copies of any public notice were dispatched to such agency, such agency will be deemed to have no objection to the issuance of the permit identified in the public notice.

§ 222.4 Initiation of hearings.

(a) In the case of any permit application for which public notice in advance of permit issuance is required in accordance with paragraph (b) of § 222.3, any person may, within 30 days of the date on which all provisions of paragraph (b) of § 222.3 have been complied with, request a public hearing to consider the issuance or denial of, or the conditions to be imposed upon, such permit. Any such request for a public hearing shall be in writing, shall identify the person requesting the hearing, shall state with particularity any objections to the issuance or denial of, or to the conditions to be imposed upon, the proposed permit, and shall state the issues which are proposed to be raised by such person for consideration at a hearing.

(b) Whenever (1) a written request satisfying the requirements of paragraph (a) of this section has been received and the Administrator or Regional Administrator, as the case may be, determines that such request presents genuine issues, or (2) the Administrator or Regional Administrator, as the case may be, determines in his discretion that a public hearing is necessary or appropriate, the Administrator or the Regional Administrator, as the case may be, will set a time and place for a public hearing in accordance with § 222.5, and will give notice of such hearing by publication in accordance with § 222.3.

(c) In the event the Administrator or the Regional Administrator, as the case may be, determines that a request filed pursuant to paragraph (a) of this section does not comply with the requirements of such paragraph (a) of this section or that such request does not present substantial issues of public interest, he shall advise, in writing, the person requesting the hearing of his determination.

§ 222.5 Time and place of hearings.

Hearings shall be held in the State in closest proximity to the proposed dump site, whenever practicable, and shall be set for the earliest practicable date no less than 30 days after the receipt of an appropriate request for a hearing or a determination by the Administrator or the Regional Administrator, as the case may be, to hold such a hearing without such a request.

§ 222.6 Presiding Officer.

A hearing convened pursuant to this Subchapter H shall be conducted by a Presiding Officer. The Administrator or Regional Administrator, as the case may be, may designate a Presiding Officer. For adjudicatory hearings held pursuant to § 222.11, the Presiding Officer shall be an EPA employee who has had no prior connection with the permit application in question, including without limitation, the performance of investigative or prosecuting functions or any other functions, and who is not employed in the Enforce-

ment Division or any Regional enforcement office.

[42 FR 2471, Jan. 11, 1977; 42 FR 6583, Feb. 3, 1977]

§ 222.7 Conduct of public hearing.

The Presiding Officer shall be responsible for the expeditious conduct of the hearing. The hearing shall be an informal public hearing, not an adversary proceeding, and shall be conducted so as to allow the presentation of public comments. When the Presiding Officer determines that it is necessary or appropriate, he shall cause a suitable record, which may include a verbatim transcript, of the proceedings to be made. Any person may appear at a public hearing convened pursuant to § 222.5 whether or not he requested the hearing, and may be represented by counsel or any other authorized representative. The Presiding Officer is authorized to set forth reasonable restrictions on the nature or amount of documentary material or testimony presented at a public hearing, giving due regard to the relevancy of any such information, and to the avoidance of undue repetitiveness of information presented.

§ 222.8 Recommendations of Presiding Officer.

Within 30 days following the adjournment of a public hearing convened pursuant to § 222.5, or within such additional period as the Administrator or the Regional Administrator, as the case may be, may grant to the Presiding Officer for good cause shown, and after full consideration of the comments received at the hearing, the Presiding Officer will prepare and forward to the Administrator or to the Regional Administrator, as the case may be, written recommendations relating to the issuance or denial of, or conditions to be imposed upon, the proposed permit and the record of the hearing, if any. Such recommendations shall contain a brief statement of the basis for the recommendations including a description of evidence relied upon. Copies of the Presiding Officer's recommendations shall be provided to any interested person on request, without charge. Copies of the record will be provided in accordance with 40 CFR Part 2.

[42 FR 2471, Jan. 11, 1977; 42 FR 6583, Feb. 3, 1977]

§ 222.9 Issuance of permits.

(a) Within 30 days following receipt of the Presiding Officer's recommendations or, where no hearing has been held, following the close of the 30-day period for requesting a hearing as provided in § 222.4, the Administrator or the Regional Administrator, as the case may be, shall make a determination with respect to the issuance, denial, or imposition of conditions on, any permit applied for under this Subchapter H and shall give notice to the applicant and to all persons who registered their attendance at the hearing by providing their name and mailing address, if any, by mailing a letter stating the determination and stating the basis therefor in terms of the Criteria.

(b) Any determination to issue or deny any permit after a hearing held pursuant to § 222.7 shall take effect no sooner than:

(1) 10 days after notice of such determination is given if no request for an adjudicatory hearing is filed in accordance with § 222.10(a); or

(2) 20 days after notice of such determination is given if a request for an adjudicatory hearing is filed in accordance with paragraph (a) of § 222.10 and the Administrator or the Regional Administrator, as the case may be, denies such request in accordance with paragraph (c) of § 222.10; or

(3) The date on which a final determination has been made following an adjudicatory hearing held pursuant to § 222.11.

(c) The Administrator or Regional Administrator, as the case may be, may extend the term of a previously issued permit pending the conclusion of the proceedings held pursuant to §§ 222.7 through 222.9.

(d) A copy of each permit issued shall be sent to the appropriate District Office of the U.S. Coast Guard.

§ 222.10 Appeal to adjudicatory hearing.

(a) Within 10 days following the receipt of notice of the issuance or

denial of any permit pursuant to § 222.9 after a hearing held pursuant to § 222.7, any interested person who participated in such hearing may request that an adjudicatory hearing be held pursuant to § 222.11 for the purpose of reviewing such determination, or any part thereof. Any such request for an adjudicatory hearing shall be filed with the Administrator or the Regional Administrator, as the case may be, and shall be in writing, shall identify the person requesting the adjudicatory hearing and shall state with particularity the objections to the determination, the basis therefor and the modification requested.

(b) Whenever a written request satisfying the requirements of paragraph (a) of this section has been received and the Administrator or Regional Administrator, as the case may be, determines that an adjudicatory hearing is warranted, the Administrator or the Regional Administrator, as the case may be, will set a time and place for an adjudicatory hearing in accordance with § 222.5, and will give notice of such hearing by publication in accordance with § 222.3.

(c) Prior to the conclusion of the adjudicatory hearing and appeal process, the Administrator or the Regional Administrator, as the case may be, in his discretion may extend the duration of a previously issued permit until a final determination has been made pursuant to § 222.11 or § 222.12.

(d) In the event the Administrator or the Regional Administrator, as the case may be, determines that a request filed pursuant to paragraph (a) of this section does not comply with the requirements of such paragraph (a) of this section or that such request does not present substantial issues of public interest, he shall advise, in writing, the person requesting the adjudicatory hearing of his determination.

(e) Any person requesting an adjudicatory hearing or requesting admission as a party to an adjudicatory hearing shall state in his written request, and shall by filing such request consent, that he and his employees and agents shall submit themselves to direct and cross-examination at any such hearing and to the taking of an oath administered by the Presiding Officer.

§ 222.11 Conduct of adjudicatory hearings.

(a) *Parties.* Any interested person may at a reasonable time prior to the commencement of the hearing submit to the Presiding Officer a request to be admitted as a party. Such request shall be in writing and shall set forth the information which would be required to be submitted by such person if he were requesting an adjudicatory hearing. Any such request to be admitted as a party which satisfies the requirements of this paragraph (a) shall be granted and all parties shall be informed at the commencement of the adjudicatory hearing of the parties involved. Any party may be represented by counsel or other authorized representative. EPA staff representing the Administrator or Regional Administrator who took action with respect to the permit application shall be deemed a party.

(b) *Filing and service.* (1) An original and two (2) copies of all documents or papers required or permitted to be filed shall be filed with the Presiding Officer.

(2) Copies of all documents and papers filed with the Presiding Officer shall be served upon all other parties to the adjudicatory hearing.

(c) *Consolidation.* The Administrator, or the Regional Administrator in the case of a hearing arising within his Region and for which he has been delegated authority hereunder, may, in his discretion, order consolidation of any adjudicatory hearings held pursuant to this section whenever he determines that consolidation will expedite or simplify the consideration of the issues presented. The Administrator may, in his discretion, order consolidation and designate one Region to be responsible for the conduct of any hearings held pursuant to this section which arise in different Regions whenever he determines that consolidation will expedite or simplify the consideration of the issues presented.

(d) *Pre-hearing conference.* The Presiding Officer may hold one or more prehearing conferences and may issue a prehearing order which may include

without limitation, requirements with respect to any or all of the following:

(1) Stipulations and admissions;

(2) Disputed issues of fact;

(3) Disputed issues of law;

(4) Admissibility of any evidence;

(5) Hearing procedures including submission of oral or written direct testimony, conduct of cross-examination, and the opportunity for oral arguments;

(6) Any other matter which may expedite the hearing or aid in disposition of any issues raised therein.

(e) *Adjudicatory hearing procedures.* (1) The burden of going forward with the evidence shall:

(i) In the case of any adjudicatory hearing held pursuant to § 222.10(b)(1), be on the person filing a request under § 222.10(a) as to each issue raised by the request; and

(ii) In the case of any adjudicatory hearing held pursuant to § 223.2 or pursuant to Part 226, be on the Environmental Protection Agency.

(2) The Presiding Officer shall have the duty to conduct a fair and impartial hearing, to take action to avoid unnecessary delay in the disposition of proceedings, and to maintain order. He shall have all powers necessary or appropriate to that end, including without limitation, the following:

(i) To administer oaths and affirmations;

(ii) To rule upon offers of proof and receive relevant evidence;

(iii) To regulate the course of the hearing and the conduct of the parties and their counsel;

(iv) To consider and rule upon all procedural and other motions appropriate to the proceedings; and

(v) To take any action authorized by these regulations and in conformance with law.

(3) Parties shall have the right to cross-examine a witness who appears at an adjudicatory hearing to the extent that such cross-examination is necessary or appropriate for a full disclosure of the facts. In multi-party proceedings the Presiding Officer may limit cross-examination to one party on each side if he is satisfied that the cross-examination by one party will adequately protect the interests of other parties.

(4) When a party will not be unfairly prejudiced thereby, the Presiding Officer may order all or part of the evidence to be submitted in written form.

(5) Rulings of the Presiding Officer on the admissibility of evidence, the propriety of cross-examination, and other procedural matters, shall be final and shall appear in the record.

(6) Interlocutory appeals may not be taken.

(7) Parties shall be presumed to have taken exception to an adverse ruling.

(8) The proceedings of all hearings shall be recorded by such means as the Presiding Officer may determine. The original transcript of the hearing shall be a part of the record and the sole official transcript. Copies of the transcript shall be available from the Environmental Protection Agency in accordance with 40 CFR Part 2.

(9) The rules of evidence shall not apply.

(f) *Decision after adjudicatory hearing.* (1) Within 30 days after the conclusion of the adjudicatory hearing, or within such additional period as the Administrator or the Regional Administrator, as the case may be, may grant to the Presiding Officer for good cause shown, the Presiding Officer shall submit to the Administrator or the Regional Administrator, as the case may be, proposed findings of fact and conclusions of law, his recommendation with respect to any and all issues raised at the hearing, and the record of the hearing. Such findings, conclusions and recommendations shall contain a brief statement of the basis for the recommendations. Copies of the Presiding Officer's proposed findings of fact, conclusions of law and recommendations shall be provided to all parties to the adjudicatory hearing on request, without charge.

(2) Within 20 days following submission of the Presiding Officer's proposed findings of fact, conclusions of law and recommendations, any party may submit written exceptions, no more than 30 pages in length, to such proposed findings, concisions and recommendations and within 30 days following the submission of the Presiding Officer's proposed findings, conclusions and recommendations any party may file written comments, no more

than 30 pages in length, on another party's exceptions. Within 45 days following the submission of the Presiding Officer's proposed findings, conclusions and recommendations, the Administrator or the Regional Administrator, as the case may be, shall make a determination with respect to all issues raised at such hearing and shall affirm, reverse or modify the previous or proposed determination, as the case may be. Notice of such determination shall set forth the determination for each such issue, shall briefly state the basis therefor and shall be given by mail to all parties to the adjudicatory hearing.

§ 222.12 Appeal to Administrator.

(a) Within 10 days following receipt of the determination of the Regional Administrator pursuant to paragraph (f)(2) of § 222.11, any party to an adjudicatory hearing held in accordance with § 222.11 may appeal such determination to the Administrator by filing a written notice of appeal, or the Administrator may, on his own initiative, review any prior determination.

(b) The notice of appeal shall be no more than 40 pages in length and shall contain:

(1) The name and address of the person filing the notice of appeal;

(2) A concise statement of the facts on which the person relies and appropriate citations to the record of the adjudicatory hearing;

(3) A concise statement of the legal basis on which the person relies;

(4) A concise statement setting forth the action which the person proposes that the Administrator take; and

(5) A certificate of service of the notice of appeal on all other parties to the adjudicatory hearing.

(c) The effective date of any determination made pursuant to paragraph (f)(2) of § 222.11 may be stayed by the Administrator pending final determination by him pursuant to this section upon the filing of a notice of appeal which satisfies the requirements of paragraph (b) of this section or upon initiation by the Administrator of review of any determination in the absence of such notice of appeal.

(d) Within 20 days following the filing of a notice of appeal in accordance with this section, any party to the adjudicatory hearing may file a written memorandum, no more than 40 pages in length, in response thereto.

(e) Within 45 days following the filing of a notice of appeal in accordance with this section, the Administrator shall render his final determination with respect to all issues raised in the appeal to the Administrator and shall affirm, reverse, or modify the previous determination and briefly state the basis for his determination.

(f) In accordance with 5 U.S.C. section 704, the filing of an appeal to the Administrator pursuant to this section shall be a prerequisite to judicial review of any determination to issue, deny or impose conditions upon any permit, or to modify, revoke or suspend any permit, or to take any other enforcement action, under this Subchapter H.

§ 222.13 Computation of time.

In computing any period of time prescribed or allowed in this part, except unless otherwise provided, the day on which the designated period of time begins to run shall not be included. The last day of the period so computed is to be included unless it is a Saturday, Sunday, or a legal holiday in which the Environmental Protection Agency is not open for business, in which event the period runs until the end of the next day which is not a Saturday, Sunday, or legal holiday. Intermediate Saturdays, Sundays and legal holidays shall be excluded from the computation when the period of time prescribed or allowed is seven days or less.

PART 223—CONTENTS OF PERMITS; REVISION, REVOCATION OR LIMITATION OF OCEAN DUMPING PERMITS UNDER SECTION 104(d) OF THE ACT

Subpart A—Contents of Ocean Dumping Permits Issued Under Section 102 of the Act

AUTHORITY: Secs. 102, 104, 107, 108, Marine Protection Research, and Sanctuaries Act of 1972, as amended (33 U.S.C. 1412, 1414, 1417, 1418).

SOURCE: 42 FR 60702, Nov. 28, 1977, unless otherwise noted.

Subpart A—Contents of Ocean Dumping Permits Issued Under Section 102 of the Act

§ 223.1 Contents of special, interim, emergency, general and research permits; posting requirements.

(a) All special, interim, emergency and research permits shall be displayed on the vessel engaged in dumping and shall include the following:

(1) Name of permittee;

(2) Means of conveyance and methods and procedures for release of the materials to be dumped;

(3) The port through or from which such material will be transported for dumping;

(4) A description of relevant physical and chemical properties of the materials to be dumped;

(5) The quantity of the material to be dumped expressed in tons;

(6) The disposal site;

(7) The times at which the permitted dumping may occur and the effective date and expiration date of the permit;

(8) Special provisions which, after consultation with the Coast Guard, are deemed necessary for monitoring or surveillance of the transportation or dumping;

(9) Such monitoring relevant to the assessment of the impact of permitted dumping activities on the marine environment at the disposal site as the Administrator or Regional Administrator, as the case may be, determine to be necessary or appropriate; and

(10) Any other terms and conditions determined by the Administrator, or Regional Administrator, as the case may be, to be necessary or appropriate, including, without limitation, release procedures and requirements for the continued investigation or development of alternatives to ocean dumping.

(b) General permits shall contain such terms and conditions as the Administrator deems necessary or appropriate.

(c) Interim permits shall, in addition to the information required or permitted to be included in the permit pursuant to paragraph (a) of this section, include terms and conditions which satisfy the requirements of §§ 220.3(d) and 227.8.

Subpart B—Procedures for Revision, Revocation or Limitation of Ocean Dumping Permits Under Section 104(d) of the Act

§ 223.2 Scope of these rules.

(a) These rules of practice shall govern all proceedings under Section 104(d) of the Marine Protection, Research, and Sanctuaries Act of 1972, as amended (33 U.S.C. 1414(d)), to revise, revoke or limit the terms and conditions of any permit issued pursuant to section 102 of the Act. Section 104(d) provides that "the Administrator * * * may limit or deny the issuance of permits, or he may alter or revoke partially or entirely the terms of permits issued by him under this title, for the transportation for dumping, or for the dumping, or both of specified materials or classes of materials, where he finds that such materials cannot be dumped consistently with the criteria and other factors required to be applied in evaluating the permit application."

(b) In the absence of specific provisions in these rules, and where appropriate, questions arising at any stage of the proceedings shall be resolved at the discretion of the Presiding Officer, the Regional Administrator, or the Administrator, as appropriate.

§ 223.3 Preliminary determination; notice.

(a) *General.* Any general, special, emergency, interim or research permit issued pursuant to section 102 of the Act shall be subject to revision, revoca-

tion or limitation, in whole or in part, as the result of a determination by the Administrator or Regional Administrator that:

(1) The cumulative impact of the permittee's dumping activities or the aggregate impact of all dumping activities at the dump site designated in the permit should be categorized as Impact Category I, as defined in § 228.10(c)(1) of this subchapter; or

(2) There has been a change in circumstances relating to the management of the disposal site designated in the permit; or

(3) The dumping authorized by the permit would violate applicable water quality standards; or

(4) The dumping authorized by the permit can no longer be carried out consistent with the criteria set forth in Parts 227 and 228.

(b) *Preliminary determination.* Whenever any person authorized by the Administrator or Regional Administrator to (1) periodically review permits pursuant to section 104(d) of the Act or (2) otherwise assess the need for revision, revocation or limitation of a permit makes any of the determinations listed in paragraph (a) of this section with respect to a permit issued pursuant to section 102 of the Act, and additionally determines that revision, revocation or limitation of such permit is warranted, the Administrator or Regional Administrator, as the case may be, shall provide notification of such proposed revision, revocation or limitation to the permittee named in the permit, if any, the public, and any cognizant Federal/State agencies pursuant to paragraph (c) of this section.

(c) *Form of notification.* Notice of any proposed revision, revocation or limitation of a permit shall be sent to the permittee by certified mail, return receipt requested, and shall be published and otherwise disseminated in the manner described in § 222.3(b) through (h).

(d) *Contents of notice.* The notice of any proposed revision, revocation or limitation of a permit issued pursuant to paragraph (b) of this section shall include, in addition to any other materials, the following:

(1) A brief description of the contents of the permit, as set forth in § 223.1;

(2) A description of the proposed revision, revocation, or limitation;

(3) A statement of the reason for such proposed revision, revocation, or limitation; and

(4) A statement that within thirty (30) days of the date of dissemination of the notice, any person may request a public hearing on the proposed revision, revocation or limitation.

§ 223.4 Request for, scheduling and conduct of public hearing; determination.

(a) *Request for hearing.* Within thirty (30) days of the date of the dissemination of any notice required by § 223.2(b), any person may request the Administrator or Regional Administrator, as appropriate, to hold a public hearing on the proposed revision, revocation or limitation by submitting a written request containing the following:

(1) Identification of the person requesting the hearing and his interest in the proceeding;

(2) A statement of any objections to the proposed revision, revocation or limitation or to any facts or reasons identified as supporting such revision, revocation or limitation; and

(3) A statement of the issues which such person proposes to raise for consideration at such hearing.

(b) *Grant or denial of hearing; notification.* Whenever (1) a written request satisfying the requirements of paragraph (a) of this section has been received, and the Administrator or Regional Administrator, as appropriate, determines that such request presents genuine issues, or (2) the Administrator or Regional Administrator, as the case may be, determines in his discretion that a public hearing is necessary or appropriate, the Administrator or Regional Administrator, as the case may be, will set a time and place for a public hearing in accordance with paragraph (c) of this section and will give notice of such hearing by publication in accordance with § 223.3(c). In the event the Administrator or the Regional Administrator, as the case may be, determines that a request filed

pursuant to paragraph (a) of this section does not comply with the requirements of paragraph (a) or that such request does not present genuine issues, he shall advise, in writing, the person requesting the hearing of his determination.

(c) *Time and place of hearing.* Any hearing authorized pursuant to this Section by the Administrator or Regional Administrator, as the case may be, shall be held in the city in which the Environmental Protection Agency Regional Office which issued the permit is located, whenever practicable, and shall be set for the earliest practicable date, but in no event less than thirty (30) days after the receipt of an appropriate request for a hearing or a determination by the Administrator or the Regional Administrator, as the case may be, to hold such a hearing without such a request.

(d) *Presiding Officer.* Any hearing convened pursuant to this part shall be conducted by a Presiding Officer, who shall be either a Regional Judicial Officer or a person having the qualifications of a Judicial Officer assigned by the Administrator or Regional Administrator, as appropriate. Such person shall be an attorney who is a permanent or temporary employee of the Agency, who is not employed by the Region's or Headquarter's Water Programs Division, Surveillance and Analysis Division, or Enforcement Division, and who has had no connection with the preparation or presentation of evidence for any hearing in which he participates as Judicial Officer.

(e) *Conduct of the public hearing.* The Presiding Officer shall be responsible for the expeditious conduct of the hearing. The hearing shall be an informal public hearing, not an adversary proceeding, and shall be conducted so as to allow the presentation of public comments. When the Presiding Officer determines that it is necessary or appropriate, he shall cause a suitable record, which may include a verbatim transcript, of the proceedings to be made. Any person may appear at a public hearing convened pursuant to this section whether or not he requested the hearing, and may be represented by counsel or any other authorized representative. The Presiding Officer is authorized to set forth reasonable restrictions on the nature or amount of documentary material or testimony presented at a public hearing, giving due regard to the relevancy of any such information, and to the avoidance of undue repetitiveness of information presented.

(f) *Recommendations of Presiding Officer.* Within 30 days following the adjournment of a public hearing convened pursuant to this section or within such additional period as the Administrator or the Regional Administrator, as the case may be, may grant to the Presiding Officer for good cause shown, and after full consideration of the comments received at the hearing, the Presiding Officer will prepare and forward to the Administrator or to the Regional Administrator, as the case may be, written recommendations relating to the revision, revocation or limitation of the permit and the record of the hearing, if any. Such recommendations shall contain a brief statement of the basis therefor, including a description of evidence relied upon (1) to support any finding made pursuant to § 223.3(a); (2) to justify any proposed revision, revocation or limitation of the permit; and (3) to justify any proposed revision, revocation or limitation which differs from that set forth in the notice issued pursuant to § 223.3(b). Copies of the Presiding Officer's recommendations shall be provided to any interested person on request, without charge. Copies of the record will be provided in accordance with 40 CFR Part 2.

(g) *Determination of the Administrator or Regional Administrator.* Upon receipt of the Presiding Officer's recommendations or, where no hearing has been held, upon termination of the thirty (30)-day period for requesting a hearing provided in paragraph (a) of this section, the Administrator or the Regional Administrator, as the case may be, shall make a determination with respect to the modification, revocation or suspension of the permit. Such determination shall include a description of the permit revision, revocation or limitation, the basis therefor, and the effective date. A copy of such determination shall be mailed to the permittee and each

person who registered his attendance at the hearing by providing his name and mailing address.

§ 223.5 Request for, scheduling and conduct of adjudicatory hearing; determination.

Within ten (10) days following the receipt of the Administrator's or Regional Administrator's determination issued pursuant to § 223.4(g), any person who participated in the public hearing held pursuant to § 223.4 may request that an adjudicatory hearing be held for the purpose of reviewing such determination or any part thereof. Such request shall be submitted and disposed of, and any adjudicatory hearing convened shall be conducted in accordance with the procedures set forth in §§ 222.10(a), (b), (d), and (e) and 222.11.

PART 224—RECORDS AND REPORTS REQUIRED OF OCEAN DUMPING PERMITTEES UNDER SECTION 102 OF THE ACT

Sec.

AUTHORITY: 33 U.S.C. 1412 and 1418.

§ 224.1 Records of permittees.

Each permittee named in a special, interim, emergency or research permit under section 102 of the Act and each person availing himself of the privilege conferred by a general permit, shall maintain complete records of the following information, which will be available for inspection by the Administrator, Regional Administrator, the Commandant of the U.S. Coast Guard, or their respective designees:

(a) The physical and chemical characteristics of the material dumped pursuant to the permit;

(b) The precise times and locations of dumping;

(c) Any other information required as a condition of a permit by the Administrator or the Regional Administrator, as the case may be.

[42 FR 2474, Jan. 11, 1977]

§ 224.2 Reports.

(a) *Periodic reports.* Information required to be recorded pursuant to § 224.1 shall be reported to the Administrator or the Regional Administrator, as the case may be, for the periods indicated within 30 days of the expiration of such periods:

(1) For each six-month period, if any, following the effective date of the permit;

(2) For any other period of less than six months ending on the expiration date of the permit; and

(3) As otherwise required in the conditions of the permit.

(b) *Reports of emergency dumping.* If material is dumped without a permit pursuant to paragraph (c)(4) of § 220.1, the owner or operator of the vessel or aircraft from which such dumping occurs shall as soon as feasible inform the Administrator, Regional Administrator, or the nearest Coast Guard district of the incident by radio, telephone, or telegraph and shall within 10 days file a written report with the Administrator or Regional Administrator containing the information required under § 224.1 and a complete description of the circumstances under which the dumping occurred. Such description shall explain how human life at sea was in danger and how the emergency dumping reduced that danger. If the material dumped included containers, the vessel owner or operator shall immediately request the U.S. Coast Guard to publish in the local Notice to Mariners the dumping location, the type of containers, and whether the contents are toxic or explosive. Notification shall also be given to the Food and Drug Administration, Shellfish Sanitation Branch, Washington, DC 20204, as soon as possible.

[42 FR 2474, Jan. 11, 1977]

PART 225—CORPS OF ENGINEERS DREDGED MATERIAL PERMITS

Sec.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2475, Jan. 11, 1977, unless otherwise noted.

§ 225.1 General.

Applications and authorizations for Dredged Material Permits under section 103 of the Act for the transportation of dredged material for the purpose of dumping it in ocean waters will be evaluated by the U.S. Army Corps of Engineers in accordance with the criteria set forth in Part 227 and processed in accordance with 33 CFR 209.120 with special attention to § 209.120(g)(17) and 33 CFR 209.145.

§ 225.2 Review of Dredged Material Permits.

(a) The District Engineer shall send a copy of the public notice to the appropriate Regional Administrator, and set forth in writing all of the following information:

(1) The location of the proposed disposal site and its physical boundaries;

(2) A statement as to whether the site has been designated for use by the Administrator pursuant to section 102(c) of the Act;

(3) If the proposed disposal site has not been designated by the Administrator, a statement of the basis for the proposed determination why no previously designated site is feasible and a description of the characteristics of the proposed disposal site necessary for its designation pursuant to Part 228 of this Subchapter H;

(4) The known historical uses of the proposed disposal site;

(5) Existence and documented effects of other authorized dumpings that have been made in the dumping area (e.g., heavy metal background reading and organic carbon content);

(6) An estimate of the length of time during which disposal will continue at the proposed site;

(7) Characteristics and composition of the dredged material; and

(8) A statement concerning a preliminary determination of the need for and/or availability of an environmental impact statement.

(b) The Regional Administrator will within 15 days of the date the public notice and other information required to be submitted by paragraph (a) of § 225.2 are received by him, review the information submitted and request from the District Engineer any additional information he deems necessary or appropriate to evaluate the proposed dumping.

(c) Using the information submitted by the District Engineer, and any other information available to him, the Regional Administrator will within 15 days after receipt of all requested information, make an independent evaluation of the proposed dumping in accordance with the criteria and respond to the District Engineer pursuant to paragraph (d) or (e) of this section. The Regional Administrator may request an extension of this 15 day period to 30 days from the District Engineer.

(d) When the Regional Administrator determines that the proposed dumping will comply with the criteria, he will so inform the District Engineer in writing.

(e) When the Regional Administrator determines that the proposed dumping will not comply with the criteria he shall so inform the District Engineer in writing. In such cases, no Dredged Material Permit for such dumping shall be issued unless and until the provisions of § 225.3 are followed and the Administrator grants a waiver of the criteria pursuant to § 225.4.

§ 225.3 Procedure for invoking economic impact.

(a) When a District Engineer's determination to issue a Dredged Material Permit for the dumping of dredged material into ocean waters has been rejected by a Regional Administrator upon application of the Criteria, the District Engineer may determine whether, under section 103(d) of the Act, there is an economically feasible alternative method or site available other than the proposed dumping in ocean waters. If the District Engineer makes any such preliminary determination that there is no economically feasible alternative method or site available, he shall so advise the Regional Administrator setting forth his reasons for such determination and shall submit a report of such determination to the Chief of Engineers in ac-

cordance with 33 CFR 209.120 and 209.145.

(b) If the decision of the Chief of Engineers is that ocean dumping at the designated site is required because of the unavailability of feasible alternatives, he shall so certify and request that the Secretary of the Army seek a waiver from the Administrator of the Criteria or of the critical site designation in accordance with § 225.4.

§ 225.4 Waiver by Administrator.

The Administrator shall grant the requested waiver unless within 30 days of his receipt of the notice, certificate and request in accordance with paragraph (b) of § 225.3 he determines in accordance with this section that the proposed dumping will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. Notice of the Administrator's final determination under this section shall be given to the Secretary of the Army.

PART 227—CRITERIA FOR THE EVALUATION OF PERMIT APPLICATIONS FOR OCEAN DUMPING OF MATERIALS

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2476, Jan. 11, 1977, unless otherwise noted.

Subpart A—General

§ 227.1 Applicability.

(a) Section 102 of the Act requires that criteria for the issuance of ocean disposal permits be promulgated after consideration of the environmental effect of the proposed dumping operation, the need for ocean dumping, alternatives to ocean dumping, and the effect of the proposed action on esthetic, recreational and economic values and on other uses of the ocean.

This Parts 227 and 228 of this Subchapter H together constitute the criteria established pursuant to section 102 of the Act. The decision of the Administrator, Regional Administrator or the District Engineer, as the case may be, to issue or deny a permit and to impose specific conditions on any permit issued will be based on an evaluation of the permit application pursuant to the criteria set forth in this Part 227 and upon the requirements for disposal site management pursuant to the criteria set forth in Part 228 of this Subchapter H.

(b) With respect to the criteria to be used in evaluating disposal of dredged materials, this section and Subparts C, D, E, and G apply in their entirety. To determine whether the proposed dumping of dredged material complies with Subpart B, only §§ 227.4, 227.5, 227.6, 227.9, 227.10 and 227.13 apply. An applicant for a permit to dump dredged material must comply with all of Subparts C, D, E, G and applicable sections of B, to be deemed to have met the EPA criteria for dredged material dumping promulgated pursuant to section 102(a) of the Act. If, in any case, the Chief of Engineers finds that, in the disposition of dredged material, there is no economically feasible method or site available other than a dumping site, the utilization of which would result in noncompliance with the criteria established pursuant to Subpart B relating to the effects of dumping or with the restrictions established pursuant to section 102(c) of the Act relating to critical areas, he shall so certify and request that the Secretary of the Army seek a waiver from the Administrator pursuant to Part 225.

(c) The Criteria of this Part 227 are established pursuant to section 102 of the Act and apply to the evaluation of proposed dumping of materials under Title I of the Act. The Criteria of this Part 227 deal with the evaluation of proposed dumping of materials on a case-by-case basis from information supplied by the applicant or otherwise available to EPA or the Corps of Engineers concerning the characteristics of the waste and other considerations relating to the proposed dumping.

(d) After consideration of the provisions of §§ 227.28 and 227.29, no permit will be issued when the dumping would result in a violation of applicable water quality standards.

§ 227.2 Materials which satisfy the environmental impact criteria of Subpart B.

(a) If the applicant satisfactorily demonstrates that the material proposed for ocean dumping satisfies the environmental impact criteria set forth in Subpart B, a permit for ocean dumping will be issued unless:

(1) There is no need for the dumping, and alternative means of disposal are available, as determined in accordance with the criteria set forth in Subpart C; or

(2) There are unacceptable adverse effects on esthetic, recreational or economic values as determined in accordance with the criteria set forth in Subpart D; or

(3) There are unacceptable adverse effects on other uses of the ocean as determined in accordance with the criteria set forth in Subpart E.

(b) If the material proposed for ocean dumping satisfies the environmental impact criteria set forth in Subpart B, but the Administrator or the Regional Administrator, as the case may be, determines that any one of the considerations set forth in paragraph (a)(1), (2) or (3) of this section applies, he will deny the permit application; provided however, that he may issue an interim permit for ocean dumping pursuant to paragraph (d) of § 220.3 and Subpart F of this Part 227 when he determines that:

(1) The material proposed for ocean dumping does not contain any of the materials listed in § 227.5 or listed in § 227.6, except as trace contaminants; and

(2) In accordance with Subpart C there is a need to ocean dump the material and no alternatives are available to such dumping; and

(3) The need for the dumping and the unavailability of alternatives, as determined in accordance with Subpart C, are of greater significance to the public interest than the potential for adverse effect on esthetic, recre-

ational or economic values, or on other uses of the ocean, as determined in accordance with Subparts D and E, respectively.

§ 227.3 Materials which do not satisfy the environmental impact criteria set forth in Subpart B.

If the material proposed for ocean dumping does not satisfy the environmental impact criteria of Subpart B, the Administrator or the Regional Administrator, as the case may be, will deny the permit application; provided however, that he may issue an interim permit pursuant to paragraph (d) of § 220.3 and Subpart F of this Part 227 when he determines that:

(a) The material proposed for dumping does not contain any of the materials listed in § 227.6 except as trace contaminants, or any of the materials listed in § 227.5;

(b) In accordance with Subpart C there is a need to ocean dump the material; and

(c) Any one of the following facters is of greater significance to the public interest than the potential for adverse impact on the marine environment, as determined in accordance with Subpart B:

(1) The need for the dumping, as determined in accordance with Subpart C; or

(2) The adverse effects of denial of the permit on recreational or economic values as determined in accordance with Subpart D; or

(3) The adverse effects of denial of the permit on other uses of the ocean, as determined in accordance with Subpart E.

Subpart B—Environmental Impact

§ 227.4 Criteria for evaluating environmental impact.

This Subpart B sets specific environmental impact prohibitions, limits, and conditions for the dumping of materials into ocean waters. If the applicable prohibitions, limits, and conditions are satisfied, it is the determination of EPA that the proposed disposal will not unduly degrade or endanger the marine environment and that the disposal will present:

(a) No unacceptable adverse effects on human health and no significant damage to the resources of the marine environment;

(b) No unacceptable adverse effect on the marine ecosystem;

(c) No unacceptable adverse persistent or permanent effects due to the dumping of the particular volumes or concentrations of these materials; and

(d) No unacceptable adverse effect on the ocean for other uses as a result of direct environmental impact.

§ 227.5 Prohibited materials.

The ocean dumping of the following materials will not be approved by EPA or the Corps of Engineers under any circumstances:

(a) High-level radioactive wastes as defined in § 227.30;

(b) Materials in whatever form (including without limitation, solids, liquids, semi-liquids, gases or organisms) produced or used for radiological, chemical or biological warfare;

(c) Materials insufficiently described by the applicant in terms of their compositions and properties to permit application of the environmental impact criteria of this Subpart B;

(d) Persistent inert synthetic or natural materials which may float or remain in suspension in the ocean in such a manner that they may interfere materially with fishing, navigation, or other legitimate uses of the ocean.

§ 227.6 Constituents prohibited as other than trace contaminants.

(a) Subject to the exclusions of paragraphs (f), (g) and (h) of this section, the ocean dumping, or transportation for dumping, of materials containing the following constituents as other than trace contaminants will not be approved on other than an emergency basis:

(1) Organohalogen compounds;

(2) Mercury and mercury compounds;

(3) Cadmium and cadmium compounds;

(4) Oil of any kind or in any form, including but not limited to petroleum, oil sludge, oil refuse, crude oil, fuel oil, heavy diesel oil, lubricating

oils, hydraulic fluids, and any mixtures containing these, transported for the purpose of dumping insofar as these are not regulated under the FWPCA;

(5) Known carcinogens, mutagens, or teratogens or materials suspected to be carcinogens, mutagens, or teratogens by responsible scientific opinion.

(b) These constituents will be considered to be present as trace contaminants only when they are present in materials otherwise acceptable for ocean dumping in such forms and amounts in liquid, suspended particulate, and solid phases that the dumping of the materials will not cause significant undesirable effects, including the possibility of danger associated with their bioaccumulation in marine organisms.

(c) The potential for significant undesirable effects due to the presence of these constituents shall be determined by application of results of bioassays on liquid, suspended particulate, and solid phases of wastes according to procedures acceptable to EPA, and for dredged material, acceptable to EPA and the Corps of Engineers. Materials shall be deemed environmentally acceptable for ocean dumping only when the following conditions are met:

(1) The liquid phase does not contain any of these constituents in concentrations which will exceed applicable marine water quality criteria after allowance for initial mixing; provided that mercury concentrations in the disposal site, after allowance for initial mixing, may exceed the average normal ambient concentrations of mercury in ocean waters at or near the dumping site which would be present in the absence of dumping, by not more than 50 percent; and

(2) Bioassay results on the suspended particulate phase of the waste do not indicate occurrence of significant mortality or significant adverse sublethal effects including bioaccumulation due to the dumping of wastes containing the constituents listed in paragraph (a) of this section. These bioassays shall be conducted with appropriate sensitive marine organisms as defined in § 227.27(c) using procedures for suspended particulate phase bioassays approved by EPA, or, for dredged material, approved by EPA and the Corps of Engineers. Procedures approved for bioassays under this section will require exposure of organisms for a sufficient period of time and under appropriate conditions to provide reasonable assurance, based on consideration of the statistical significance of effects at the 95 percent confidence level, that, when the materials are dumped, no significant undesirable effects will occur due either to chronic toxicity or to bioaccumulation of the constituents listed in paragraph (a) of this section; and

(3) Bioassay results on the solid phase of the wastes do not indicate occurrence of significant mortality or significant adverse sublethal effects due to the dumping of wastes containing the constituents listed in paragraph (a) of this section. These bioassays shall be conducted with appropriate sensitive benthic marine organisms using benthic bioassay procedures approved by EPA, or, for dredged material, approved by EPA and the Corps of Engineers. Procedures approved for bioassays under this section will require exposure of organisms for a sufficient period of time to provide reasonable assurance, based on considerations of statistical significance of effects at the 95 percent confidence level, that, when the materials are dumped, no significant undesirable effects will occur due either to chronic toxicity or to bioaccumulation of the constituents listed in paragraph (a) of this section; and

(4) For persistent organohalogens not included in the applicable marine water quality criteria, bioassay results on the liquid phase of the waste show that such compounds are not present in concentrations large enough to cause significant undesirable effects due either to chronic toxicity or to bioaccumulation in marine organisms after allowance for initial mixing.

(d) When the Administrator, Regional Administrator or District Engineer, as the case may be, has reasonable cause to believe that a material proposed for ocean dumping contains compounds identified as carcinogens, mutagens, or teratogens for which criteria have not been included in the ap-

plicable marine water quality criteria, he may require special studies to be done prior to issuance of a permit to determine the impact of disposal on human health and/or marine ecosystems. Such studies must provide information comparable to that required under paragraph (c)(3) of this section.

(e) The criteria stated in paragraphs (c)(2) and (3) of this section will become mandatory as soon as announcement of the availability of acceptable procedures is made in the FEDERAL REGISTER. At that time the interim criteria contained in paragraph (e) of this section shall no longer be applicable.

NOTE: The remainder of this paragraph has been made inapplicable by the notice of "Availability of Implementation Manual, 'Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters,'" Federal Register, Vo. 42, NO. 7, 7 September 1977, page 44835.

(f) The prohibitions and limitations of this section do not apply to the constituents identified in paragraph (a) of this section when the applicant can demonstrate that such constituents are (1) present in the material only as chemical compounds or forms (e.g., inert insoluble solid materials) nontoxic to marine life and non-bioaccumulative in the marine environment upon disposal and thereafter, or (2) present in the material only as chemical compounds or forms which, at the time of dumping and thereafter, will be rapidly rendered non-toxic to marine life and non-bioaccumulative in the marine environment by chemical or biological degradation in the sea; provided they will not make edible marine organisms unpalatable; or will not endanger human health or that of domestic animals, fish, shellfish, or wildlife.

(g) The prohibitions and limitations of this section do not apply to the constituents identified in paragraph (a) of this section for the granting of research permits if the substances are rapidly rendered harmless by physical, chemical or biological processes in the sea; provided they will not make edible marine organisms unpalatable and will not endanger human health or that of domestic animals.

(h) The prohibitions and limitations of this section do not apply to the constituents identified in paragraph (a) of this section for the granting of permits for the transport of these substances for the purpose of incineration at sea if the applicant can demonstrate that the stack emissions consist of substances which are rapidly rendered harmless by physical, chemical or biological processes in the sea. Incinerator operations shall comply with requirements which will be established on a case-by-case basis.

[42 FR 2476, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 227.7 Limits established for specific wastes or waste constituents.

Materials containing the following constituents must meet the additional limitations specified in this section to be deemed acceptable for ocean dumping:

(a) Liquid waste constituents immiscible with or slightly soluble in seawater, such as benzene, xylene, carbon disulfide and toluene, may be dumped only when they are present in the waste in concentrations below their solubility limits in seawater. This provision does not apply to materials which may interact with ocean water to form insoluble materials;

(b) Radioactive materials, other than those prohibited by § 227.5, must be contained in accordance with the provisions of § 227.11 to prevent their direct dispersion or dilution in ocean waters;

(c) Wastes containing living organisms may not be dumped if the organisms present would endanger human health or that of domestic animals, fish, shellfish and wildlife by:

(1) Extending the range of biological pests, viruses, pathogenic microorganisms or other agents capable of infesting, infecting or extensively and permanently altering the normal populations of organisms;

(2) Degrading uninfected areas; or

§ 227.7 Limits established for specific wastes or waste constituents.

Materials containing the following constituents must meet the additional limitations specified in this section to be deemed acceptable for ocean dumping:

(a) Liquid waste constituents immiscible with or slightly soluble in seawater, such as benzene, xylene, carbon disulfide and toluene, may be dumped only when they are present in the waste in concentrations below their solubility limits in seawater. This provision does not apply to materials which may interact with ocean water to form insoluble materials;

(b) Radioactive materials, other than those prohibited by § 227.5, must be contained in accordance with the provisions of § 227.11 to prevent their direct dispersion or dilution in ocean waters;

(c) Wastes containing living organisms may not be dumped if the organisms present would endanger human health or that of domestic animals, fish, shellfish and wildlife by:

(1) Extending the range of biological pests, viruses, pathogenic microorganisms or other agents capable of infesting, infecting or extensively and permanently altering the normal populations of organisms;

(2) Degrading uninfected areas; or

(3) Introducing viable species not indigenous to an area.

(d) In the dumping of wastes of highly acidic or alkaline nature into the ocean, consideration shall be given to:

(1) The effects of any change in acidity or alkalinity of the water at the disposal site; and

(2) The potential for synergistic effects or for the formation of toxic compounds at or near the disposal site. Allowance may be made in the permit conditions for the capability of ocean waters to neutralize acid or alkaline wastes; provided, however, that dumping conditions must be such that the average total alkalinity or total acidity of the ocean water after allowance for initial mixing, as defined in § 227.29, may be changed, based on stoichiometric calculations, by no more than 10 percent during all dumping operations at a site to neutralize acid or alkaline wastes.

(e) Wastes containing biodegradable constituents, or constituents which consume oxygen in any fashion, may be dumped in the ocean only under conditions in which the dissolved oxygen after allowance for initial mixing, as defined in § 227.29, will not be depressed by more than 25 percent below the normally anticipated ambient conditions in the disposal area at the time of dumping.

§ 227.8 Limitations on the disposal rates of toxic wastes.

No wastes will be deemed acceptable for ocean dumping unless such wastes can be dumped so as not to exceed the limiting permissible concentration as defined in § 227.27; *Provided*, That this § 227.8 does not apply to those wastes for which specific criteria are established in § 227.11 or § 227.12. Total quantities of wastes dumped at a site may be limited as described in § 228.8.

§ 227.9 Limitations on quantities of waste materials.

Substances which may damage the ocean environment due to the quantities in which they are dumped, or which may seriously reduce amenities, may be dumped only when the quantities to be dumped at a single time and place are controlled to prevent long-term damage to the environment or to amenities.

§ 227.10 Hazards to fishing, navigation, shorelines or beaches.

(a) Wastes which may present a serious obstacle to fishing or navigation may be dumped only at disposal sites and under conditions which will insure no unacceptable interference with fishing or navigation.

(b) Wastes which may present a hazard to shorelines or beaches may be dumped only at sites and under conditions which will insure no unacceptable danger to shorelines or beaches.

§ 227.11 Containerized wastes.

(a) Wastes containerized solely for transport to the dumping site and ex-

pected to rupture or leak on impact or shortly thereafter must meet the appropriate requirements of §§ 227.6, 227.7, 227.8, 227.9, and 227.10.

(b) Other containerized wastes will be approved for dumping only under the following conditions:

(1) The materials to be disposed of decay, decompose or radiodecay to environmentally innocuous materials within the life expectancy of the containers and/or their inert matrix: and

(2) Materials to be dumped are present in such quantities and are of such nature that only short-term localized adverse effects will occur should the containers rupture at any time; and

(3) Containers are dumped at depths and locations where they will cause no threat to navigation, fishing, shorelines, or beaches.

§ 227.12 Insoluble wastes.

(a) Solid wastes consisting of inert natural minerals or materials compatible with the ocean environment may be generally approved for ocean dumping provided they are insoluble above the applicable trace or limiting permissible concentrations and are rapidly and completely settleable, and they are of a particle size and density that they would be deposited or rapidly dispersed without damage to benthic, demersal, or pelagic biota.

(b) Persistent inert synthetic or natural materials which may float or remain in suspension in the ocean as prohibited in paragraph (d) of § 227.5 may be dumped in the ocean only when they have been processed in such a fashion that they will sink to the bottom and remain in place.

§ 227.13 Dredged materials.

(a) Dredged materials are bottom sediments or materials that have been dredged or excavated from the navigable waters of the United States, and their disposal into ocean waters is regulated by the U.S. Army Corps of Engineers using the criteria of applicable sections of Parts 227 and 228. Dredged material consists primarily of natural sediments or materials which may be contaminated by municipal or industrial wastes or by runoff from terrestrial sources such as agricultural lands.

(b) Dredged material which meets the criteria set forth in the following paragraphs (b)(1), (2), or (3) of this section is environmentally acceptable for ocean dumping without further testing under this section:

(1) Dredged material is composed predominantly of sand, gravel, rock, or any other naturally occurring bottom material with particle sizes larger than silt, and the material is found in areas of high current or wave energy such as streams with large bed loads or coastal areas with shifting bars and channels; or

(2) Dredged material is for beach nourishment or restoration and is composed predominantly of sand, gravel or shell with particle sizes compatible with material on the receiving beaches; or

(3) *When:* (i) The material proposed for dumping is substantially the same as the substrate at the proposed disposal site; and

(ii) The site from which the material proposed for dumping is to be taken is far removed from known existing and historical sources of pollution so as to provide reasonable assurance that such material has not been contaminated by such pollution.

(c) When dredged material proposed for ocean dumping does not meet the criteria of paragraph (b) of this section, further testing of the liquid, suspended particulate, and solid phases, as defined in § 227.32, is required. Based on the results of such testing, dredged material can be considered to be environmentally acceptable for ocean dumping only under the following conditions:

(1) The material is in compliance with the requirements of § 227.6; and

(2)(i) All major constituents of the liquid phase are in compliance with the applicable marine water quality criteria after allowance for initial mixing; or

(ii) When the liquid phase contains major constituents not included in the applicable marine water quality criteria, or there is reason to suspect synergistic effects of certain contaminants, bioassays on the liquid phase of the dredged material show that it can be

discharged so as not to exceed the limiting permissible concentration as defined in paragraph (a) of § 227.27; and

(3) Bioassays on the suspended particulate and solid phases show that it can be discharged so as not to exceed the limiting permissible concentration as defined in paragraph (b) of § 227.27.

(d) For the purposes of paragraph (c)(2) of this section, major constituents to be analyzed in the liquid phase are those deemed critical by the District Engineer, after evaluating and considering any comments received from the Regional Administrator, and considering known sources of discharges in the area.

Subpart C—Need for Ocean Dumping

§ 227.14 Criteria for evaluating the need for ocean dumping and alternatives to ocean dumping.

This Subpart C states the basis on which an evaluation will be made of the need for ocean dumping, and alternatives to ocean dumping. The nature of these factors does not permit the promulgation of specific quantitative criteria of each permit application. These factors will therefore be evaluated if applicable for each proposed dumping on an individual basis using the guidelines specified in this Subpart C.

§ 227.15 Factors considered.

The need for dumping will be determined by evaluation of the following factors:

(a) Degree of treatment useful and feasible for the waste to be dumped, and whether or not the waste material has been or will be treated to this degree before dumping;

(b) Raw materials and manufacturing or other processes resulting in the waste, and whether or not these materials or processes are essential to the provision of the applicant's goods or services, or if other less polluting materials or processes could be used;

(c) The relative environmental risks, impact and cost for ocean dumping as opposed to other feasible alternatives including but not limited to:

(1) Land fill;

(2) Well injection;

(3) Incineration;

(4) Spread of material over open ground;

(5) Recycling of material for reuse;

(6) Additional biological, chemical, or physical treatment of intermediate or final waste streams;

(7) Storage.

(d) Irreversible or irretrievable consequences of the use of alternatives to ocean dumping.

§ 227.16 Basis for determination of need for ocean dumping.

(a) A need for ocean dumping will be considered to have been demonstrated when a thorough evaluation of the factors listed in § 227.15 has been made, and the Administrator, Regional Administrator or District Engineer, as the case may be, has determined that the following conditions exist where applicable:

(1) There are no practicable improvements which can be made in process technology or in overall waste treatment to reduce the adverse impacts of the waste on the total environment;

(2) There are no practicable alternative locations and methods of disposal or recycling available, including without limitation, storage until treatment facilities are completed, which have less adverse environmental impact or potential risk to other parts of the environment than ocean dumping.

(b) For purposes of paragraph (a) of this section, waste treatment or improvements in processes and alternative methods of disposal are practicable when they are available at reasonable incremental cost and energy expenditures, which need not be competitive with the costs of ocean dumping, taking into account the environmental benefits derived from such activity, including the relative adverse environmental impacts associated with the use of alternatives to ocean dumping.

(c) The duration of permits issued under Subchapter H and other terms and conditions imposed in those permits shall be determined after taking into account the factors set forth in this section. Notwithstanding compliance with Subparts B, D, and E of this Part 227 permittees may, on the basis

of the need for and alternatives to ocean dumping, be required to terminate all ocean dumping by a specified date, to phase out all ocean dumping over a specified period or periods, to continue research and development of alternative methods of disposal and make periodic reports of such research and development in order to provide additional information for periodic review of the need for and alternatives to ocean dumping, or to take such other action as the Administrator, the Regional Administrator, or District Engineer, as the case may be, determines to be necessary or appropriate.

Subpart D—Impact of the Proposed Dumping on Esthetic, Recreational and Economic Values

§ 227.17 Basis for determination.

(a) The impact of dumping on esthetic, recreational and economic values will be evaluated on an individual basis using the following considerations:

(1) Potential for affecting recreational use and values of ocean waters, inshore waters, beaches, or shorelines;

(2) Potential for affecting the recreational and commercial values of living marine resources.

(b) For all proposed dumping, full consideration will be given to such nonquantifiable aspects of esthetic, recreational and economic impact as:

(1) Responsible public concern for the consequences of the proposed dumping;

(2) Consequences of not authorizing the dumping including without limitation, the impact on esthetic, recreational and economic values with respect to the municipalities and industries involved.

§ 227.18 Factors considered.

The assessment of the potential for impacts on esthetic, recreational and economic values will be based on an evaluation of the appropriate characteristics of the material to be dumped, allowing for conservative rates of dilution, dispersion, and biochemical degradation during movement of the materials from a disposal site to an area of significant recreational or commercial value. The following specific factors will be considered in making such an assessment:

(a) Nature and extent of present and potential recreational and commercial use of areas which might be affected by the proposed dumping;

(b) Existing water quality, and nature and extent of disposal activities, in the areas which might be affected by the proposed dumping;

(c) Applicable water quality standards;

(d) Visible characteristics of the materials (e.g., color, suspended particulates) which result in an unacceptable estetic nuisance in recreational areas;

(e) Presence in the material of pathogenic organisms which may cause a public health hazard either directly or through contamination of fisheries or shellfisheries;

(f) Presence in the material of toxic chemical constituents released in volumes which may affect humans directly;

(g) Presence in the material of chemical constituents which may be bioaccumulated or persistent and may have an adverse effect on humans directly or through food chain interactions;

(h) Presence in the material of any constituents which might significantly affect living marine resources of recreational or commercial value.

§ 227.19 Assessment of impact.

An overall assessment of the proposed dumping and possible alternative methods of disposal or recycling will be made based on the effect on esthetic, recreational and economic values based on the factors set forth in this Subpart D, including where applicable, enhancement of these values, and the results of the assessment will be expressed, where possible, on a quantitative basis, such as percentage of a resource lost, reduction in use days of recreational areas, or dollars lost in commercial fishery profits or the profitability of other commercial enterprises.

Subpart E—Impact of the Proposed Dumping on Other Uses of the Ocean

§ 227.20 Basis for determination.

(a) Based on current state of the art, consideration must be given to any possible long-range effects of even the most innocuous substances when dumped in the ocean on a continuing basis. Such a consideration is made in evaluating the relationship of each proposed disposal activity in relationship to its potential for long-range impact on other uses of the ocean.

(b) An evaluation will be made on an individual basis for each proposed dumping of material of the potential for effects on uses of the ocean for purposes other than material disposal. The factors to be considered in this evaluation include those stated in Subpart D, but the evaluation of this Subpart E will be based on the impact of the proposed dumping on specific uses of the ocean rather than on overall esthetic, recreational and economic values.

§ 227.21 Uses considered.

An appraisal will be made of the nature and extent of existing and potential uses of the disposal site itself and of any areas which might reasonably be expected to be affected by the proposed dumping, and a quantitative and qualitative evaluation made, where feasible, of the impact of the proposed dumping on each use. The uses considered shall include, but not be limited to:

(a) Commercial fishing in open ocean areas;

(b) Commercial fishing in coastal areas;

(c) Commercial fishing in estuarine areas;

(d) Recreational fishing in open ocean areas;

(e) Recreational fishing in coastal areas;

(f) Recreational fishing in estuarine areas;

(g) Recreational use of shorelines and beaches;

(h) Commercial navigation;

(i) Recreational navigation;

(j) Actual or anticipated exploitation of living marine resources;

(k) Actual or anticipated exploitation of non-living resources, including without limitation, sand and gravel places and other mineral deposits, oil and gas exploration and development and offshore marine terminal or other structure development; and

(l) Scientific research and study.

§ 227.22 Assessment of impact.

The assessment of impact on other uses of the ocean will consider both temporary and long-range effects within the state of the art, but particular emphasis will be placed on any irreversible or irretrievable commitment of resources that would result from the proposed dumping.

Subpart F—Special Requirements for Interim Permits Under Section 102 of the Act

§ 227.23 General requirement.

Each interim permit issued under section 102 of the Act will include a requirement for the development and implementation, as soon as practicable, of a plan which requires, at the discretion of the Administrator or Regional Administrator, as the case may be, either:

(a) Elimination of ocean disposal of the waste, or

(b) Bringing the waste into compliance with all the criteria for acceptable ocean disposal.

§ 227.24 Contents of environmental assessment.

A plan developed pursuant to this Subpart F must include an environmental assessment of the proposed action, including without limitation:

(a) Description of the proposed action;

(b) A thorough review of the actual need for dumping;

(c) Environmental impact of the proposed action;

(d) Adverse impacts which cannot be avoided should the proposal be implemented;

(e) Alternatives to the proposed action;

(f) Relationship between short-term uses of man's environment and the

maintenance and enhancement of long-term productivity;

(g) Irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented; and

(h) A discussion of problems and objections raised by other Federal, State and local agencies and by interested persons in the review process.

§ 227.25 Contents of plans.

In addition to the environmental assessment required by § 227.24, a plan developed pursuant to this Subpart F must include a schedule for eliminating ocean dumping or bringing the wastes into compliance with the environmental impact criteria of Subpart B, including without limitation, the following:

(a) If the waste is treated to the degree necessary to bring it into compliance with the ocean dumping criteria, the applicant should provide a description of the treatment and a scheduled program for treatment and a subsequent analysis of treated material to prove the effectiveness of the process.

(b) If treatment cannot be effected by post-process techniques the applicant should, determining the offending constituents, examine his raw materials and his total process to determine the origin of the pollutant. If the offending constituents are found in the raw material the applicant should consider a new supplier and provide an analysis of the new material to prove compliance. Raw materials are to include all water used in the process. Water from municipal sources complying with drinking water standards is acceptable. Water from other sources such as private wells should be analyzed for contaminants. Water that has been used in the process should be considered for treatment and recycling as an additional source of process water.

(c) If offending constituents are a result of the process, the applicant should investigate and describe the source of the constituents. A report of this information will be submitted to EPA and the applicant will then submit a proposal describing possible alternatives to the existing process or processes and level of cost and effectiveness.

(d) If an acceptable alternative to ocean dumping or additional control technology is required, a schedule and documentation for implementation of the alternative or approved control process shall be submitted and shall include, without limitation:

(1) Engineering plan;

(2) Financing approval;

(3) Starting date for change;

(4) Completiodate;

(5) Operation starting date.

(e) If an acceptable alternative does not exist at the time the application is submitted, the applicant will submit an acceptable in-house research program or employ a competent research institution to study the problem. The program of research must be approved by the Administrator or Regional Administrator, as the case may be, before the initiation of the research. The schedule and documentation for implementation of a research program will include, without limitation:

(1) Approaches;

(2) Experimental design;

(3) Starting date;

(4) Reporting intervals;

(5) Proposed completion date;

(6) Date for submission of final report.

§ 227.26 Implementation of plans.

Implementation of each phase of a plan shall be initiated as soon as it is approved by the Administrator or Regional Administrator, as the case may be.

Subpart G—Definitions

§ 227.27 Limiting permissible concentration (LPC).

(a) The limiting permissible concentration of the liquid phase of a material is:

(1) That concentration of a constituent which, after allowance for initial mixing as provided in § 227.29, does not exceed applicable marine water quality criteria; or, when there are no applicable marine water quality criteria,

(2) That concentration of waste or dredged material in the receiving

water which, after allowance for initial mixing, as specified in § 227.29, will not exceed a toxicity threshold defined as 0.01 of a concentration shown to be acutely toxic to appropriate sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures.

(3) When there is reasonable scientific evidence on a specific waste material to justify the use of an application factor other than 0.01 as specified in paragraph (a)(2) of this section, such alternative application factor shall be used in calculating the LPC.

(b) The limiting permissible concentration of the suspended particulate and solid phases of a material means that concentration which will not cause unreasonable acute or chronic toxicity or other sublethal adverse effects based on bioassay results using appropriate sensitive marine organisms in the case of the suspended particulate phase, or appropriate sensitive benthic marine organisms in the case of the solid phase; and which will not cause accumulation of toxic materials in the human food chain. These bioassays are to be conducted in accordance with procedures approved by EPA, or, in the case of dredged material, approved by EPA and the Corps of Engineers.[1]

(c) "Appropriate sensitive marine organisms" means at least one species each representative of phytoplankton or zooplankton, crustacean or mollusk, and fish species chosen from among the most sensitive species documented in the scientific literature or accepted by EPA as being reliable test organisms to determine the anticipated impact of the wastes on the ecosystem at the disposal site. Bioassays, except on phytoplankton or zooplankton, shall be run for a minimum of 96 hours under temperature, salinity, and dissolved oxygen conditions representing the extremes of environmental stress at the disposal site. Bioassays on phytoplankton or zooplankton may be run for shorter periods of time as appropriate for the organisms tested at the discretion of EPA, or EPA and the Corps of Engineers, as the case may be.

(d) "Appropriate sensitive benthic marine organisms" means at least one species each representing filter-feeding, deposit-feeding, and burrowing species chosen from among the most sensitive species accepted by EPA as being reliable test organisms to determine the anticipated impact on the site; provided, however, that until sufficient species are adequately tested and documented, interim guidance on appropriate organisms available for use will be provided by the Administrator, Regional Administrator, or the District Engineer, as the case may be.

[42 FR 2476, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 227.28 Release zone.

The release zone is the area swept out by the locus of points constantly 100 meters from the perimeter of the conveyance engaged in dumping activities, beginning at the first moment in which dumping is scheduled to occur and ending at the last moment in which dumping is scheduled to occur. No release zone shall exceed the total surface area of the dumpsite.

§ 227.29 Initial mixing.

(a) Initial mixing is defined to be that dispersion or diffusion of liquid, suspended particulate, and solid phases of a waste which occurs within four hours after dumping. The limiting permissible concentration shall not be exceeded beyond the boundaries of the disposal site during initial mixing, and shall not be exceeded at any point in the marine environment after initial mixing. The maximum concentration of the liquid, suspended particulate, and solid phases of a dumped material after initial mixing shall be estimated by one of these methods, in order of preference:

(1) When field data on the proposed dumping are adequate to predict ini-

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[1] An implementation manual is being developed jointly by EPA and the Corps of Engineers, and announcement of the availability of the manual will be published in the FEDERAL REGISTER. Until this manual is available, interim guidance on the appropriate procedures can be obtained from the Marine Protection Branch, WH-548, Environmental Protection Agency, 401 M Street SW, Washington, DC 20460, or the Corps of Engineers, as the case may be.

tial dispersion and diffusion of the waste, these shall be used, if necessary, in conjunction with an appropriate mathematical model acceptable to EPA or the District Engineer, as appropriate.

(2) When field data on the dispersion and diffusion of a waste of characteristics similar to that proposed for discharge are available, these shall be used in conjunction with an appropriate mathematical model acceptable to EPA or the District Engineer, as appropriate.

(3) When no field data are available, theoretical oceanic turbulent diffusion relationships may be applied to known characteristics of the waste and the disposal site.

(b) When no other means of estimation are feasible.

(1) The liquid and suspended particulate phases of the dumped waste may be assumed to be evenly distributed after four hours over a column of water bounded on the surface by the release zone and extending to the ocean floor, thermocline, or halocline if one exists, or to a depth of 20 meters, whichever is shallower, and

(2) The solid phase of a dumped waste may be assumed to settle rapidly to the ocean bottom and to be distributed evenly over the ocean bottom in an area equal to that of the release zone as defined in § 227.28.

(c) When there is reasonable scientific evidence to demonstrate that other methods of estimating a reasonable allowance for initial mixing are appropriate for a specific material, such methods may be used with the concurrence of EPA after appropriate scientific review.

§ 227.30 High-level radioactive waste.

High-level radioactive waste means the aqueous waste resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated waste from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuels or irradiated fuel from nuclear power reactors.

§ 227.31 Applicable marine water quality criteria.

Applicable marine water quality criteria means the criteria given for marine waters in the EPA publication "Quality Criteria for Water" as published in 1976 and amended by subsequent supplements or additions.

§ 227.32 Liquid, suspended particulate, and solid phases of a material.

(a) For the purposes of these regulations, the liquid phase of a material, subject to the exclusions of paragraph (b) of this section, is the supernatant remaining after one hour undisturbed settling, after centrifugation and filtration through a 0.45 micron filter. The suspended particulate phase is the supernatant as obtained above prior to centrifugation and filtration. The solid phase includes all material settling to the bottom in one hour. Settling shall be conducted according to procedures approved by EPA.

(b) For dredged material, other material containing large proportions of insoluble matter, materials which may interact with ocean water to form insoluble matter or new toxic compounds, or materials which may release toxic compounds upon deposition, the Administrator, Regional Administrator, or the District Engineer, as the case may be, may require that the separation of liquid, suspended particulate, and solid phases of the material be performed upon a mixture of the waste with ocean water rather than on the material itself. In such cases the following procedures shall be used:

(1) For dredged material, the liquid phase is considered to be the centrifuged and 0.45 micron filtered supernatant remaining after one hour undisturbed settling of the mixture resulting from a vigorous 30-minute agitation of one part bottom sediment from the dredging site with four parts water (vol/vol) collected from the dredging site or from the disposal site, as appropriate for the type of dredging operation. The suspended particulate phase is the supernatant as obtained above prior to centrifugation and filtration. The solid phase is considered to be all material settling to

the bottom within one hour. Settling shall be conducted by procedures approved by EPA and the Corps of Engineers.

(2) For other materials, the proportion of ocean water used shall be the minimum amount necessary to produce the anticipated effect (e.g., complete neutralization of an acid or alkaline waste) based on guidance provided by EPA on particular cases, or in accordance with approved EPA procedures. For such materials the liquid phase is the filtered and centrifuged supernatant resulting from the mixture after 30 minutes of vigorous shaking followed by undisturbed settling for one hour. The suspended particulate phase is the supernatant as obtained above prior to centrifugation and filtration. The solid phase is the insoluble material settling to the bottom in that period.

PART 228—CRITERIA FOR THE MANAGEMENT OF DISPOSAL SITES FOR OCEAN DUMPING

Sec.

AUTHORITY: 33 U.S.C. 1412 and 1418.

SOURCE: 42 FR 2482, Jan. 11, 1977, unless otherwise noted.

§ 228.1 Applicability.

The criteria of this Part 228 are established pursuant to section 102 of the Act and apply to the evaluation of proposed ocean dumping under Title I of the Act. The criteria of this Part 228 deal with the evaluation of the proposed dumping of material in ocean waters in relation to continuing requirements for effective management of ocean disposal sites to prevent unreasonable degradation of the marine environment from all wastes being dumped in the ocean. This Part 228 is applicable to dredged material disposal sites only as specified in §§ 228.4(e), 228.9, and 228.12.

§ 228.2 Definitions.

(a) The term "disposal site" means an interim or finally approved and precise geographical area within which ocean dumping of wastes is permitted under conditions specified in permits issued under sections 102 and 103 of the Act. Such sites are identified by boundaries established by (1) coordinates of latitude and longitude for each corner, or by (2) coordinates of latitude and longitude for the center point and a radius in nautical miles from that point. Boundary coordinates shall be identified as precisely as is warranted by the accuracy with which the site can be located with existing navigational aids or by the implantation of transponders, buoys or other means of marking the site.

(b) The term "baseline" or "trend assessment" survey means the planned sampling or measurement of parameters at set stations or in set areas in and near disposal sites for a period of time sufficient to provide synoptic data for determining water quality, benthic, or biological conditions as a result of ocean disposal operations. The minimum requirements for such surveys are given in § 228.13.

(c) The term "disposal site evaluation study" means the collection, analysis, and interpretation of all pertinent information available concerning an existing disposal site, including but not limited to, data and information from trend assessment surveys, monitoring surveys, special purpose surveys of other Federal agencies, public data archives, and social and economic studies and records of affected areas.

(d) The term "disposal site designation study" means the collection, analysis and interpretation of all available pertinent data and information on a proposed disposal site prior to use, in-

cluding but not limited to, that from baseline surveys, special purpose surveys of other Federal agencies, public data archives, and social and economic studies and records of areas which would be affected by use of the proposed site.

(e) The term "management authority" means the EPA organizational entity assigned responsibility for implementing the management functions identified in § 228.3.

(f) "Statistical significance" shall mean the statistical significance determined by using appropriate standard techniques of multivariate analysis with results interpreted at the 95 percent confidence level and based on data relating species which are present in sufficient numbers at control areas to permit a valid statistical comparison with the areas being tested.

(g) "Valuable commercial and recreational species" shall mean those species for which catch statistics are compiled on a routine basis by the Federal or State agency responsible for compiling such statistics for the general geographical area impacted, or which are under current study by such Federal or State agencies for potential development for commercial or recreational use.

(h) "Normal ambient value" means that concentration of a chemical species reasonably anticipated to be present in the water column, sediments, or biota in the absence of disposal activities at the disposal site in question.

§ 228.3 Disposal site management responsibilities.

(a) Management of a site consists of regulating times, rates, and methods of disposal and quantities and types of materials disposed of; developing and maintaining effective ambient monitoring programs for the site; conducting disposal site evaluation and designation studies; and recommending modifications in site use and/or designation (e.g., termination of use of the site for general use or for disposal of specific wastes).

(b) Each site, upon interim or continuing use designation, will be assigned to either an EPA Regional office or to EPA Headquarters for management. These designations will be consistent with the delegation of authority in § 220.4. The designated management authority is fully responsible for all aspects of the management of sites within the general requirements specified in § 220.4 and this section. Specific requirements for meeting the management responsibilities assigned to the designated management authority for each site are outlined in §§ 228.5 and 228.6.

§ 228.4 Procedures for designation of sites.

(a) *General Permits.* Geographical areas or regions within which materials may be dumped under a general permit will be published as part of the promulgation of each general permit.

(b) *Special and Interim Permits.* Areas where ocean dumping is permitted subject to the specific conditions of individual special or interim permits, will be designated by promulgation in this Part 228, and such designation will be made based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the impact of waste disposal on areas similar to such sites in physical, chemical, and biological characteristics. All studies for the evaluation and potential selection of dumping sites will be conducted in accordance with the requirements of §§ 228.5 and 228.6.

The Administrator may, from time to time, designate specific locations for temporary use for disposal of small amounts of materials under a special permit only without disposal site designation studies when such materials satisfy the Criteria and the Administrator determines that the quantities to be disposed of at such sites will not result in significant impact on the environment. Such designations will be done by promulgation in this Part 228, and will be for a specified period of time and for specified quantities of materials.

(c) *Emergency Permits.* Dumping sites for materials disposed of under an emergency permit will be specified by the Administrator as a permit condition and will be based on an individual appraisal of the characteristics of

the waste and the safest means for its disposal.

(d) *Research Permits.* Dumping sites for research permits will be determined by the nature of the proposed study. Dumping sites will be specified by the Administrator as a permit condition.

(e) *Dredged Material Permits.*

(1) Areas where ocean dumping of dredged material is permitted subject to the specific conditions of Dredged Material permits issued by the U.S. Army Corps of Engineers will be designated by EPA promulgation in this Part 228, and such designation will be made based on environmental studies of each site, regions adjacent to the site, and on historical knowledge of the impact of dredged material disposal on areas similar to such sites in physical, chemical, and biological characteristics. All studies for the evaluation and potential selection of dredged material disposal sites will be conducted in accordance with the appropriate requirements of §§ 228.5 and 228.6, except that:

(i) Baseline or trend assessment requirements may be developed on a case-by-case basis from the results of research, including that now in progress by the Corps of Engineers.

(ii) An environmental impact assessment for all sites within a particular geographic area may be prepared based on complete disposal site designation or evaluation studies on a typical site or sites in that area. In such cases, sufficient studies to demonstrate the generic similarity of all sites within such a geographic area will be conducted.

(2) In those cases where a recommended disposal site has not been designated by the Administrator, or where it is not feasible to utilize a recommended disposal site that has been designated by the Administrator, the District Engineer shall, in consultation with EPA, select a site in accordance with the requirements of §§ 228.5 and 228.6(a). Concurrence by EPA in permits issued for the use of such site for the dumping of dredged material at the site will constitute EPA approval of the use of the site for dredged material disposal only.

(3) Sites designated for the ocean dumping of dredged material in accordance with the procedures of paragraph (e)(1) or (2) of this section shall be used only for the ocean dumping of dredged material under permits issued by the U.S. Army Corps of Engineers.

§ 228.5 General criteria for the selection of sites.

(a) The dumping of materials into the ocean will be permitted only at sites or in areas selected to minimize the interference of disposal activities with other activities in the marine environment, particularly avoiding areas of existing fisheries or shellfisheries, and regions of heavy commercial or recreational navigation.

(b) Locations and boundaries of disposal sites will be so chosen that temporary perturbations in water quality or other environmental conditions during initial mixing caused by disposal operations anywhere within the site can be expected to be reduced to normal ambient seawater levels or to undetectable contaminant concentrations or effects before reaching any beach, shoreline, marine sanctuary, or known geographically limited fishery or shellfishery.

(c) If at any time during or after disposal site evaluation studies, it is determined that existing disposal sites presently approved on an interim basis for ocean dumping do not meet the criteria for site selection set forth in §§ 228.5 through 228.6, the use of such sites will be terminated as soon as suitable alternate disposal sites can be designated.

(d) The sizes of ocean disposal sites will be limited in order to localize for identification and control any immediate adverse impacts and permit the implementation of effective monitoring and surveillance programs to prevent adverse long-range impacts. The size, configuration, and location of any disposal site will be determined as a part of the disposal site evaluation or designation study.

(e) EPA will, wherever feasible, designate ocean dumping sites beyond the edge of the continental shelf and other such sites that have been historically used.

§ 228.6 Specific criteria for site selection.

(a) In the selection of disposal sites, in addition to other necessary or appropriate factors determined by the Administrator, the following factors will be considered:

(1) Geographical position, depth of water, bottom topography and distance from coast;

(2) Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases;

(3) Location in relation to beaches and other amenity areas;

(4) Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any;

(5) Feasibility of surveillance and monitoring;

(6) Dispersal, horizontal transport and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any;

(7) Existence and effects of current and previous discharges and dumping in the area (including cumulative effects);

(8) Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance and other legitimate uses of the ocean;

(9) The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys;

(10) Potentiality for the development or recruitment of nuisance species in the disposal site;

(11) Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

(b) The results of a disposal site evaluation and/or designation study based on the criteria stated in paragraphs (b)(1) through (11) of this section will be presented in support of the site designation promulgation as an environmental assessment of the impact of the use of the site for disposal, and will be used in the preparation of an environmental impact statement for each site where such a statement is required by EPA policy. By publication of a notice in accordance with this Part 228, an environmental impact statement, in draft form, will be made available for public comment not later than the time of publication of the site designation as proposed rulemaking, and a final EIS will be made available at the time of final rulemaking.

§ 228.7 Regulation of disposal site use.

Where necessary, disposal site use will be regulated by setting limitations on times of dumping and rates of discharge, and establishing a disposal site monitoring program.

§ 228.8 Limitations on times and rates of disposal.

Limitations as to time for and rates of dumping may be stated as part of the promulgation of site designation. The times and the quantities of permitted material disposal will be regulated by the EPA management authority so that the limits for the site as specified in the site designation are not exceeded. This will be accomplished by the denial of permits for the disposal of some materials, by the imposition of appropriate conditions on other permits and, if necessary, the designation of new disposal sites under the procedures of § 228.4. In no case may the total volume of material disposed of at any site under special or interim permits cause the concentration of the total materials or any constituent of any of the materials being disposed of at the site to exceed limits specified in the site designation.

§ 228.9 Disposal site monitoring.

(a) The monitoring program, if deemed necessary by the Regional Administrator or the District Engineer, as appropriate, may include baseline or trend assessment surveys by EPA, NOAA, other Federal agencies, or contractors, special studies by permittees, and the analysis and interpretation of data from remote or automatic sampling and/or sensing devices. The primary purpose of the monitoring program is to evaluate the impact of disposal on the marine environment by referencing the monitoring results to a set of baseline conditions. When disposal sites are being used on a continu-

ing basis, such programs may consist of the following components:

(1) Trend assessment surveys conducted at intervals frequent enough to assess the extent and trends of environmental impact. Until survey data or other information are adequate to show that changes in frequency or scope are necessary or desirable, trend assessment and baseline surveys should generally conform to the applicable requirements of § 228.13. These surveys shall be the responsibility of the Federal government.

(2) Special studies conducted by the permittee to identify immediate and short-term impacts of disposal operations.

(b) These surveys may be supplemented, where feasible and useful, by data collected from the use of automatic sampling buoys, satellites or in situ platforms, and from experimental programs.

(c) EPA will require the full participation of permittees, and encourage the full participation of other Federal and State and local agencies in the development and implementation of disposal site monitoring programs. The monitoring and research programs presently supported by permittees may be incorporated into the overall monitoring program insofar as feasible.

§ 228.10 Evaluating disposal impact.

(a) Impact of the disposal at each site designated under section 102 of the Act will be evaluated periodically and a report will be submitted as appropriate as part of the Annual Report to Congress. Such reports will be prepared by or under the direction of the EPA management authority for a specific site and will be based on an evaluation of all data available from baseline and trend assessment surveys, monitoring surveys, and other data pertinent to conditions at and near a site.

(b) The following types of effects, in addition to other necessary or appropriate considerations, will be considered in determining to what extent the marine environment has been impacted by materials disposed of at an ocean disposal site:

(1) Movement of materials into estuaries or marine sanctuaries, or onto oceanfront beaches, or shorelines;

(2) Movement of materials toward productive fishery or shellfishery areas;

(3) Absence from the disposal site of pollution-sensitive biota characteristic of the general area;

(4) Progressive, non-seasonal, changes in water quality or sediment composition at the disposal site, when these changes are attributable to materials disposed of at the site;

(5) Progressive, non-seasonal, changes in composition or numbers of pelagic, demersal, or benthic biota at or near the disposal site, when these changes can be attributed to the effects of materials disposed of at the site;

(6) Accumulation of material constituents (including without limitation, human pathogens) in marine biota at or near the site.

(c) The determination of the overall severity of disposal at the site on the marine environment, including without limitation, the disposal site and adjacent areas, will be based on the evaluation of the entire body of pertinent data using appropriate methods of data analysis for the quantity and type of data available. Impacts will be categorized according to the overall condition of the environment of the disposal site and adjacent areas based on the determination by the EPA management authority assessing the nature and extent of the effects identified in paragraph (b) of this section in addition to other necessary or appropriate considerations. The following categories shall be used:

(1) *Impact Category I*: The effects of activities at the disposal site shall be categorized in Impact Category I when one or more of the following conditions is present and can reasonably be attributed to ocean dumping activities;

(i) There is identifiable progressive movement or accumulation, in detectable concentrations above normal ambient values, of any waste or waste constituent from the disposal site within 12 nautical miles of any shoreline, marine sanctuary designated under Title III of the Act, or critical area

designated under section 102(c) of the Act; or

(ii) The biota, sediments, or water column of the disposal site, or of any area outside the disposal site where any waste or waste constituent from the disposal site is present in detectable concentrations above normal ambient values, are adversely affected by the toxicity of such waste or waste constituent to the extent that there are statistically significant decreases in the populations of valuable commercial or recreational species, or of specific species of biota essential to the propagation of such species, within the disposal site and such other area as compared to populations of the same organisms in comparable locations outside such site and area; or

(iii) Solid waste material disposed of at the site has accumulated at the site or in areas adjacent to it, to such an extent that major uses of the site or of adjacent areas are significantly impaired and the Federal or State agency responsible for regulating such uses certifies that such significant impairment has occurred and states in its certificate the basis for its determination of such impairment; or

(iv) There are adverse effects on the taste or odor of valuable commercial or recreational species as a result of disposal activities; or

(v) When any toxic waste, toxic waste constituent, or toxic byproduct of waste interaction, is consistently identified in toxic concentrations above normal ambient values outside the disposal site more than 4 hours after disposal.

(2) *Impact Category II*: The effects of activities at the disposal site which are not categorized in Impact Category I shall be categorized in Impact Category II.

§ 228.11 Modification in disposal site use.

(a) Modifications in disposal site use which involve the withdrawal of designated disposal sites from use or permanent changes in the total specified quantities or types of wastes permitted to be discharged to a specific disposal site will be made through promulgation of an amendment to the disposal site designation set forth in this Part 228 and will be based on the results of the analyses of impact described in § 228.10 or upon changed circumstances concerning use of the site.

(b) Modifications in disposal site use promulgated pursuant to paragraph (a) of this section shall not automatically modify conditions of any outstanding permit issued pursuant to this Subchapter H, and provided further that unless the EPA management authority for such site modifies, revokes or suspends such permit or any of the terms or conditions of such permit in accordance with the provisions of § 232.2 based on the results of impact analyses as described in § 228.10 or upon changed circumstances concerning use of the site, such permit will remain in force until its expiration date.

(c) When the EPA management authority determines that activities at a disposal site have placed the site in Impact Category I, the Administrator or the Regional Administrator, as the case may be, shall place such limitations on the use of the site as are necessary to reduce the impacts to acceptable levels.

(d) The determination of the Administrator as to whether to terminate or limit use of a disposal site will be based on the impact of disposal at the site itself and on the Criteria.

[42 FR 2482, Jan. 11, 1977; 43 FR 1071, Jan. 6, 1978]

§ 228.12 Delegation of management authority for interim ocean dumping sites.

(a) The following sites are approved for dumping the indicated materials on an interim basis pending completion of baseline or trend assessment surveys and designation for continuing use or termination of use. Management authority for all sites is delegated to the EPA organizational entity under which each site is listed. The sizes and use specifications are based on historical usage and do not necessarily meet the criteria stated in this part.

(1) The following sites for disposal of dredged material under Corps of Engineers permits under section 103 of the Act will remain in force according to the following schedule:

(i) Until such time as formal rulemaking is completed or until December 31, 1988, whichever is sooner:

(A) [Reserved] (See editorial note three at end of section.)

(B) Georgetown, SC.

(C) Pascagoula, MS.

(D) Humboldt Bay, CA.

(E) Long Beach, CA.

(F) San Diego, CA (2 sites).

(G) New Jersey/Long Island Sites (8 sites): Absecon Inlet, NJ; Cold Spring Inlet, NJ; Manasquan Inlet, NJ; East Rockaway, NY; Jones Inlet, NY; Fire Island, NY; Shark River, NJ; and Rockaway Inlet, NY.

(H) [Reserved]

(ii) Until such time as formal rulemaking is completed or until July 31, 1988, whichever is sooner:

(A)-(O) [Reserved] (See editorial note three at end of section.)

(2) The interim designations of the following sites are terminated effective immediately:

(i) Both Region I industrial waste sites.

(ii) Region II wreck site.

(iii) Region III acid wastes site.

(iv) Region IV industrial wastes site.

(v) The Region VI industrial waste site located at 28d 00' to 28d 10' N. and 89d 15' to 89d 30' W.

(vi) Port Mansfield Channel Disposal Area 1-A.

(3) The interim designations of all other dredged material sites listed in § 228.12(a) and the Region II wood incineration site are extended indefinitely, pending completion of the present studies and determination of the need for continuing use of these sites, the completion of any necessary studies, and evaluation of their suitability. Designation studies for particular sites within this group will begin as soon as feasible after the completion of nearby sites presently being studied.

APPROVED INTERIM DUMPING SITES

Location (latitude, longitude)	EPA region	Primary use
43°33'00" N., 69°55'00" W., 1 nautical mile radius	I	Industrial wastes.
42°25'42" N., 70°35'00" W., 1 nautical mile radius	I	Do.
40°22'30" N. to 40°25'00" N., 73°41'30" W. to 78°45'00" W	II	Municipal sewage sludge.
40°16'00" N. to 40°20'00" N., 73°36'00" W. to 73°40'00" W	II	Acid wastes.
40°23'00" N., 73°49'00" W., 0.6 nautical mile radius	II	Cellar dirt.
40°10'00" N., 73°42'00" W., 0.5 nautical mile radius	II	Wrecks.
19°10'00" N. to 19°20'00" N., 66°35'00" W. to 66°50'00" W	II	Industrial wastes.
38°30'00" N. to 38°35'00" N., 74°15'00" W. to 74°25'00" W	III	Acid wastes.
38°20'00" N. to 38°25'00" N., 74°10'00" W. to 74°20'00" W	III	Municipal sewage sludge.
31°46'00" N., 80°30'00" W., 31°47'06" N., 80°29'00" W., 31°48'00" N., 80°30'30" W., 31°46'30" N., 80°32'00" W.	IV	Industrial wastes.
27°12'00" N. to 27°28'00" N., 94°28'00" W. to 94°44'00" W	VI	Do.
28°00'00" N. to 28°10'00" N., 89°15'00" W. to 89°30'00" W	VI	Do.
40°00'00" N. to 40°04'20" N., 73°41'00" W. to 73°38'10" W	II	Incineration of wood.

DREDGED MATERIAL SITES

(All dredged material sites will be retained under EPA Headquarters management until formally approved for continuing use or otherwise assigned for Regional management prior to such designation.)

LOCATION (LAT., LONG.)

Newburyport, MA—42°48'50" N., 70°47'00" W.; (½ N. Mi. square).

Marblehead, MA—42°25'42" N., 70°34'00" W. (2 N. Mi. diameter).

Boston, MA—41°49'00" N., 70°25'00" W. (1 N. Mi. diameter).

Cape Arundel, ME—43°17'45" N., 70°27'12" W. (500 yds. diameter).

Absecon Inlet—39°21'07" N., 74°23'40" W.; 39°21'18" N., 74°23'53" W.

Cold Spring Inlet—38°55'41" N., 74°53'05" W.; 38°55'33" N., 74°53'23" W.

Manasquan Inlet—40°06'22" N., 74°01'46" W.; 40°06'38" N., 74°01'39" W.

East Rockaway—40°34'36" N., 73°49'00" W.; 40°35'06" N., 73°47'06" W.; 40°34'10" N., 73°48'36" W.; 40°34'12" N., 73°47'17" W.

Jones Inlet—40°34'32" N., 73°39'14" W.; 40°34'32" N., 73°37'06" W.; 40°33'48" N., 73°37'06" W.; 40°33'48" N., 73°39'14" W.

Fire Island—40°36'49" N., 73°23'50" W.; 40°37'12" N., 73°21'30" W.; 40°36'41" N., 73°21'20" W.; 40°36'10" N., 73°23'40" W.

Mud Dump—40°23'48" N., 73°51'28" W.; 40°21'48" N., 73°50'00" W.; 40°21'48" N., 73°51'28" W.; 40°23'48" N., 73°50'00" W.

Shark River—40°12'48" N., 73°59'45" W.; 40°12'44" N., 73°59'06" W.; 40°11'36" N., 73°59'28" W.; 40°11'42" N., 74°00'12" W.

Rockaway Inlet—40°32'30" N., 73°55'00" W.; 40°32'30" N., 73°54'00" W., 40°32'00" N., 73°54'00" W.; 40°32'00" N., 73°55'00" W.

Mayaguez Harbor, PR—18°15'30" N., 67°14'31" W.; 18°15'30" N., 67°13'29" W.; 18°14'30" N., 67°13'29" W.; 18°14'30" N., 67°14'31" W.

Arecibo Harbor, PR—18°30'00" N., 66°42'45" W.; 18°30'00" N., 66°43'47" W.; 18°31'00" N., 66°43'47" W.; 18°31'00" N., 66°42'45" W.

Ponce Harbor, PR—17°55'30" N., 66°38'29" W.; 17°55'30" N., 66°39'31" W.; 17°54'30" N., 66°38'29" W.; 17°54'30" N., 66°39'31" W.

Yabucoa Harbor, PR—18°00'54" N., 65°44'23" W.; 18°01'33" N., 65°45'58" W.; 18°03'12" N., 65°45'42" W.; 18°02'30" N., 65°43'43" W.

Georgetown Harbor—33°11'18" N., 79°07'20" W.; 33°11'18" N., 79°05'23" W.; 33°10'38" N., 79°07'21" W.; 33°10'38" N., 79°07'21" W.

Port Royal Harbor—32°10'11" N., 80°36'00" W.; 32°10'06" N., 80°36'35" W.; 32°08'38" N., 80°36'23" W.; 32°08'41" N., 80°35'49" W.

Port Royal Harbor—32°05'46" N., 80°35'30" W.; 32°05'42" N., 80°36'27" W.; 32°04'22" N., 80°36'16" W.; 32°04'27" N., 80°35'18" W.

Brunswick Harbor—Atlantic outlet, Ga., St. Simons Sound, Brunswick Harbor Bar Channel, maintenance dredging disposal area 1 nautical mile wide by 2 nautical miles long adjacent to the channel located on the south side of the entrance and being 6.6 nautical miles from shore at a point of beginning at 31°02'35" N. and 81°17'40" W., thence due east to 31°02'35" N. and 81°16'30" W., thence due south to 31°00'30" N. and 81°16'30" W., thence due west to 31°00'30" N. and 81°17'40" W., thence due north to the point of beginning.

Canaveral Harbor—28°19'53" N., 80°31'08" W.; 28°18'50" N., 80°29'40" W.; 28°17'35" N., 80°30'52" W.; 28°18'38" N., 80°32'20" W.

Fort Pierce Harbor—27°28'30" N., 80°12'33" W.; 27°28'30" N., 80°11'27" W.; 27°27'30" N., 80°11'27" W.; 27°27'30" N., 80°12'33" W.

Jacksonville Harbor—30°21'30" N., 81°18'34" W.; 30°21'30" N., 81°17'26" W.; 30°20'30" N., 81°17'26" W.; 30°20'30" N., 81°18'34" W.

Miami Beach—25°45'30" N., 80°03'54" W.; 25°45'30" N., 80°02'50" W.; 25°44'30" N., 80°02'50" W.; 25°44'30" N., 80°03'54" W.

Palm Beach Harbor—26°46'10" N., 80°02'00" W.; 26°45'54" N., 80°02'06" W.; 26°45'54" N., 80°02'13" W.; 26°46'10" N., 80°02'07" W.

Port Everglades Harbor—26°07'00" N., 80°04'30" W.; 26°07'00" N., 80°03'30" W.; 26°06'00" N., 80°03'30" W.; 26°06'00" N., 80°04'30" W.

Charlotte Harbor—26°37'36" N., 82°19'55" W.; 26°37'36" N., 82°18'47" W.; 26°36'36" N., 82°18'47" W.; 26°36'36" N., 82°19'55" W.

Tampa Harbor—27°38'08" N., 82°55'06" W.; 27°38'08" N., 82°54'00" W.; 27°37'08" N., 82°54'00" W.; 27°37'08" N., 82°55'06" W.

Tampa Harbor—27°37'28" N., 83°00'09" W.; 27°37'34" N., 82°59'19" W.; 27°36'43" N., 82°59'13" W.; 27°36'37" N., 83°00'03" W.

Palm Beach Harbor—26°46'00" N., 79°58'55" W.; 26°46'00" N., 79°57'47" W.; 26°45'00" N., 79°57'47" W.; 26°45'00" N., 79°58'55" W.

Key West—24°27'24" N., 81°45'38" W.; 24°27'24" N., 81°44'32" W.; 24°26'20" N., 81°44'32" W.; 24°26'20" N., 81°45'38" W.

Pascagoula, MS—30°11.9' N., 88°33.1' W.; 30°11.9' N., 88°32.3' W.; 30°11.6' N., 88°32.4' W.; 30°11.6' N., 88°32.1' W.; 30°10.5' N., 88°33.2' W.; 30°10.6' N., 88°34.0' W.

Panama City, FL—30°07.1' N., 85°45.9' W.; 30°07.2' N., 85°45.5' W.; 30°06.9' N., 85°45.1' W.; 30°06.7' N., 85°45.6' W.

Port St. Joe, FL—29°50.9' N., 85°29.9' W.; 29°51.3' N., 85°29.5' W.; 29°49.2' N., 85°28.2' W.; 29°49.0' N., 85°28.8' W.

Port St. Joe, FL—29°53.9' N., 85°31.8' W.; 29°54.1' N., 85° 31.3' W.; 29°52.2' N., 85°30.1' W.; 29°52.2' N., 85°30.8' W.

GALVESTON HARBOR AND CHANNEL, TEXAS

Disposal Area No. 1—Beginning at lat. 29°18'00", long. 94°39'30"; thence to lat. 29°15'54", long. 94°37'06"; thence to lat. 29°14'24", long. 94°38'42"; thence to lat. 29°16'54", long. 94°41'30"; thence to point of beginning.

FREEPORT HARBOR, TEXAS

Disposal Area No. 1—Beginning at lat. 28°54'42", long. 95°17'38"; thence to lat. 28°54'-3"; long. 95°16'54"; thence to lat. 28°53'48", long. 95°17'27"; thence to lat. 28°54'21", long. 95°18'03"; thence to point of beginning.

MATAGORDA SHIP CHANNEL

Disposal Area No. 1—Beginning at lat. 28°24'31", long. 96°18'48"; thence to lat. 28°23'27", long. 96°17'38"; thence to lat. 28°23'15", long. 96°17'54"; thence to lat. 28°24'18", long. 96°19'03"; thence to point of beginning.

CORPUS CHRISTI SHIP CHANNEL

Disposal Area No. 1—Beginning at lat. 27°49'34", long. 97°01'51"; thence to lat. 27°48'28", long. 96°59'49"; thence to lat. 27°48'18", long 96°59'56"; thence to lat. 27°49'23", long. 97°01'58"; thence to point of beginning.

PORT MANSFIELD CHANNEL

Disposal Area No. 1—Beginning at lat. 26°34'09", long. 97°15'52"; thence to lat. 26°34'09", long. 97°15'18"; thence to lat.

26°33'57", long. 97°15'18"; thence to lat. 26°33'57", long. 97°15'52"; thence to point of beginning.

Disposal Area No. 1-A—Beginning at lat. 26°34'17", long. 97°16'12"; thence to lat. 26°34'18", long. 97°15'55"; thence to lat. 26°33'59", long. 97°15'52"; thence to lat. 26°33'58", long. 97°16'11"; thence to point of beginning.

BRAZOS ISLAND HARBOR

Disposal Area No. 1—Beginning at lat. 26°04'38", long. 97°07'52"; thence to lat. 26°04'38", long. 97°07'42"; thence to lat. 26°04'05", long. 97°06'42"; thence to lat. 26°04'05", long. 97°07'52"; thence to point of beginning.

Mississippi River, Gulf Outlet, La.—Breton Sound and Bar Channel. Maintenance dredging disposal area 0.5 mile wide by 12.5 miles long, parallel to the channel and located on the south side. Beginning at 29°32'23" N. and 89°12'20" W., following channel centerline (azimuth 308°47') in Breton Sound to 29°29'15" N. and 89°07'06" W., following centerline (azimuth 300°36') of the gulf entrance channel to 29°25'06" N. and 88°59'54" W., thence to 29°24'45" N. and 89°00'09" W., thence to 29°28'53" N., and 89°08'08" W., thence to 29°31'41" N. and 89°12'09" W., thence to the point of beginning.

Mississippi River, Baton Rouge to the Gulf of Mexico, La.—South Pass. Maintenance dredging disposal area 0.5 mile square, parallel to the channel and located on the west side. Beginning at 28°58'33" N. and 89°07'00" W., following channel centerline (azimuth 295°41') of the gulf entrance channel to 28°58'24" N. and 89°06'30" W., thence to 28°57'54" N. and 89°06'42" W., thence to 28°58'06" N. and 89°07'18" W., thence to the point of beginning.

Mississippi River, Baton Rouge to the Gulf of Mexico, La.—Southwest Pass. Maintenance dredging disposal area 2 miles square, parallel to the channel and located on the west side. Beginning at 28°54'24" N. and 89°26'03" W., following channel centerline (azimuth 0°09') of the gulf entrance channel to 28°52'18" N. and 89°26'03" W., thence to 28°52'18" N. and 89°27'48" W., thence to 28°54'24"N. and 89°27'48"W., thence to the point of beginning.

Mississippi River Outlets, Venice, La.—Tiger Pass. Maintenance dredging disposal area 0.5 mile wide by 2.5 miles long, parallel and adjacent to the channel and located on the south side. Beginning at 29°08'24" W. and 89°25'35" N. following 270° azimuth to 29°08'24" W. and 89°28'05" N., thence to 29°07'54" W. and 89°28'05" N., thence to 29°07'54" W. and 89°25'35" N., thence to the point of beginning.

Waterway from Empire, La. to the Gulf of Mexico—Bar channel. Maintenance dredging disposal area 0.5 mile wide by 1 mile long, parallel to the channel and located on the west side. Beginning at 29°15'06" N. and 89°36'30" W., following channel centerline (azimuth 11°08') of the gulf entrance channel to 29°14'30" N. and 89°36'36" W., thence to 29°14'36" N. and 89°36'48" W., thence to 29°15'12" N. and 89°36'42" W., thence to the point of beginning.

Barataria Bay Waterway, La.—Bar channel. Maintenance dredging disposal area 0.5 miles wide by 2 miles long, parallel to the channel and located on the east side 1,500 feet distance from the channel. Beginning at 29°16'13" N. and 89°55'54" W., following azimuth 312°07' to 29°14'45" N. and 89°54'05" W., thence to 29°14'30.5" N. and 89°53'45" W., thence to 29°15'54" N. and 89°55'34", thence to the point of beginning.

Bayou Lafourche and Lafourche—Jump Waterway, La.—Bell Pass. Maintenance dredging disposal area 2,000 feet wide by 1.5 miles long, parallel to the channel and located on the west side. Beginning at 29°05'00" N. and 90°13'45" W., following Bell Pass centerline (azimuth 12°55') in the gulf entrance channel to 29°03'51" N. and 90°14'06" W., thence to 29°03'57" N. and 90°14'21" W., thence to 29°05'06" N. and 90°14'03" W., thence to the point of beginning.

Houma Navigation Canal, La.—Cat Island Pass. Maintenance dredging disposal area approximately 0.5 miles wide by 5 miles long parallel to the Cat Island Channel and located on the west side 1,000 feet from the channel centerline. Beginning at 29°05'30" N. and 90°34'41" W., following azimuth 358°41' to 29°03'39.5" N. and 90°34'38.5" W., following azimuth 354° to 29°01'10" N. and 90°34'20" W., thence to 29°01'10" N. and 90°34'54" W., thence to 29°03'39.5" N. and 90°35'12" W., thence to 29°05'30" N. and 90°35'14" W., thence to the point of beginning.

Atchafalaya River—Morgan City to the Gulf of Mexico, La. and Atchafalaya River and Bayous Chene, Boeuf and Black, La.—Bar channel. Maintenance dredging disposal area 0.5 mile wide by 12 miles long, parallel to the bar channel and located on the east side. Beginning at 29°20'50" N. and 91°24'03" W., following channel centerline (azimuth 37°57') of the gulf entrance channel to 29°11'35" N. and 91°32'10" W., thence to 29°11'21" N. and 91°31'37" W., thence to 29°20'36" N. and 91°23'27" W., thence to the point of beginning.

Freshwater Bayou, La.—Bar channel. Maintenance dredging disposal area 2,000 feet wide by 3.5 miles long, parallel to the channel and located on the west side. Beginning at 29°32'00" N. and 92°18'48" W.,

following channel centerline (azimuth 09°25') of the gulf entrance to 29°28'24" N. and 92°19'30" W., thence to 29°28'25" N. and 92°19'42" W., thence to 29°32'01" N. and 92°19'00" W., thence to the point of beginning.

Mermentau River, La. Maintenance dredging disposal areas 0.5 mile wide and 1.5 miles long, parallel to the entrance channels in the Lower Mermentau River and in the Lower Mud Lake, both located on the west side:

Disposal Area "A", Mermentau River, La. Beginning at 29°44'48" N. and 93°07'12" W., following channel centerline (azimuth 256°59') of the gulf entrance to 29°43'39" N. and 93°07'36" W., thence to 29°43'42" N. and 93°07'48" W., thence to 29°44'51" N. and 93°07'24" W., thence to the point of beginning.

Disposal Area "B", Mermentau River, La. Beginning at 29°43'24" N. and 93°01'54" W., following channel centerline (azimuth 359°50') of the gulf centerline to 29°42'33" N. and 93°02'12" W., thence to 29°42'36" N. and 93°02'24" W., thence to 29°43'36" N. and 93°02'06" W., thence to the point of beginning.

Crescent City Harbor—41°43'15" N., 124°12'10" W., (1,000 yd. diameter)

Humboldt Bay Harbor—40°45'44" N., 124°15'42" W. (500 yd. diameter)

Noyo River—39°25'45" N., 123°49'42" W. (500 yd. diameter)

Farallon Islands—37°31'45" N., 122°59'00" W. (1,000 yd. radius)

San Francisco Channel Bar—37°45'06" N., 122°35'45" W. (5,000 yds. x 1,000 yds.)

Moss Landing 100 fathom—36°47'53" N., 121°49'04" W. (500 yd. radius)

Moss Landing—36°48'05" N., 121°47'22" W. (50 yds. seaward of pier)

Port Hueneme—34°05'00" N., 119°14'00" W. (1,000 yd. radius)

Los Angeles—33°37'06" N., 118°17'24" W. (1,000 yd. radius)

Newport Beach—33°31'42" N., 117°54'48" W. (1,000 yd. radius)

San Diego—Point Loma—32°35'00" N., 117°17'30" W., (1,000 yd. radius)

San Diego 100 fathom—32°36'50" N., 117°20'40" W. (1,000 yd. radius)

Honolulu Harbor—21°14'30" N., 157°54'30" W. (1,000 yd. radius)

Kauai—Nawiliwili—21°55'30" N., 159°17'00" W. (1,000 yd. radius)

Kauai—Hanapepe—21°50'18" N., 159°35'30" W. (1,000 yd. radius)

Guam—Apra Harbor—13°29'30" N., 144°34'30" E. (1,000 yd. radius)

Mouth of Columbia River—46°14'37" N., 124°10'34" W.; 46°13'53" N., 124°10'01" W.; 46°13'43" N., 124°10'26" W.; 46°14'28" N., 124°10'59" W.

Mouth of Columbia River—46°13'03" N., 124°06'17" W.; 46°12'50" N., 124°05'55" W.; 46°12'13" N., 124°06'43" W.; 46°12'26" N., 124°07'05"W.

Mouth of Columbia River—46°15'43" N., 124°05'21" W.; 46°15'36" N., 124°05'11" W.; 46°15'11" N., 124°05'53" W.; 46°15'18" N., 124°06'03" W.

Mouth of Columbia River—46°12'12" N., 124°09'00" W.; 46°12'00" N., 124°08'42" W.; 46°11'48" N., 124°09'00" W.; 46°12'00" N., 124°09'18" W.

Mouth of Columbia River—46°12'05" N., 124°05'46" W.; 46°11'52" N., 124°05'25" W.; 46°11'15" N., 124°06'14" W.; 46°11'28" N., 124°06'35" W.

Chetco River Entrance—42°01'56" N., 124°16'33" W.; 42°01'56" N., 124°16'09" W.; 42°01'38" N., 124°16'09" W.; 42°01'38" N., 124°16'33" W.

Rogue River Entrance—42°24'16" N., 124°26'48" W.; 42°24'04" N., 124°26'35" W.; 42°23'40" N., 124°27'13" W.; 42°23'52" N., 124°27'26" W.

Coquille River Entrance—43°07'54" N., 124°27'04" W.; 43°07'30" N., 124°26'27" W.; 43°07'20" N., 124°26'40" W.; 43°07'44" N., 124°27'17" W.

Coos Bay Entrance—43°21'59" N., 124°22'45" W.; 43°21'48" N., 124°21'59" W.; 43°21'35" N., 124°22'05" W.; 43°21'46" N., 124°22'51"W.

Coos Bay Entrance—43°22'44" N., 124°22'18" W.; 43°22'29" N., 124°21'34" W.; 43°22'16" N., 124°21'42" W.; 43°22'31" N., 124°22'26" W.

Umpqua River Entrance—43°40'07" N., 124°14'18" W.; 43°40'07" N., 124°13'42" W.; 43°39'53" N., 124°13'42" W.; 43°39'53" N., 124°14'18"W.

Suislaw River Entrance—44°01'32" N., 124°09'37" W.; 44°01'22" N., 124°09'02" W.; 44°01'14" N., 124°09'07" W.; 44°01'24" N., 124°09'42" W.

Tillamook Bay Entrance—45°34'09" N., 123°59'37" W.; 45°34'09" N., 123°58'45" W.; 45°33'55" N., 123°58'45" W.; 45°33'55" N., 123°59'37" W.

Depoe Bay—44°48'33" N., 124°03'53" W.; 44°48'32" N., 124°03'43" W.; 44°48'15" N., 124°03'45" W.; 44°48'16" N., 124°03'55" W.

Depoe Bay—44°48'09" N., 124°05'05" W.; 44°48'09"N., 124°04'55" W.; 44°47'53" N., 124°04'55" W.; 44°47'53" N., 124°05'05" W.

Yaquina Bay and Harbor Entrance—44°36'31" N., 124°06'04" W.; 44°36'31" N., 124°05'16" W.; 44°36'17" N., 124°05'16" W.; 44°36'17" N., 124°06'04" W.

Port Orford—42°44'08" N., 124°29'38" W.; 42°44'08" N., 124°29'28" W.; 42°43'52" N., 124°29'28" W.; 42°43'52"N., 124°29'38" W.

Willapa Bay—46°44'00" N., 124°10'00" W.; 46°39'00" N., 124°09'00" W.

Nome—West Site—64°30'04" N.

Nome—East Site—64°29'54" N., 165°24'41" W., 64°29'45" N., 165°23'27" W., 64°28'57" N., 165°23'29" W., 64°29'07" N., 165°24'25" W.

Anchorage Harbor—61°14'07" N., 149°53'56" W.; 61°14'16" N., 149°54'15" W.; 61°14'45" N., 149°53'36" W.; 61°14'36" N., 149°53'17" W.

Fish Cannery Wastes Site—Region IX.
Location:
Latitude—14d22'S;
Longitude—170d41'W (center point).
Size: 1 nautical mile in diameter.
Depth: 1,200 meters (4,000 feet).
Primary Use: Fish cannery wastes.
Period of Use: Site will expire (36 months after date of publication).
Restriction: Disposal shall be limtied to not more than 130,000 tons per year of fish cannery wastes generated on the island of Tutuila, American Samoa.

(b) The following sites are designated "Approved Ocean Dumping Sites" for continuing use, subject to the listed restrictions:

(1) Gulf Ocean Incineration Site—Headquarters.
Location—Latitude and Longitude—
26°20'00" N. to 27°00'00" N.;
93°20'00" to 94°00'00" W.
Size—(square miles) 1892.
Depth—(feet) 4500.
Primary Use: At sea incineration primarily for organochlorine wastes. Incineration of other wastes will require research studies or equivalent technical documentation to determine acceptability for ocean incineration.
Period of use: Continuing use.
Restriction: Only one ship will be permitted to burn wastes at a time, except under extreme emergencies.

(2) Herbicide Orange Incineration Site—Headquarters.
Location—Latitude and Longitude—
15°45' to 17°45' north latitude;
171°30' to 173°30' west longitude.
Size—14,400 sq. n. mi.
Depth—greater than 15,000 feet.
Use—solely for at sea incineration of Herbicide Orange by the United States Air Force aboard the *M/T Vulcanus*, owned and operated by Ocean Combustion Service.
Period of Use—May 15, 1977, to September 30, 1977. The designation of this site will be withdrawn after this period of use.

(3) Kwajalein Ocean dumping site—Region IX.
Location—Latitude and Longitude—
08° 47' north latitude,
167° 36' east longitude.
Size—1,000 yard radius.
Depth—1,655 fathoms (9,930 feet).
Primary use—waste materials resulting from the operation of the Kwajalein Missile Range.
Period of use—Three years after issuance of an ocean dumping permit for use of this site.

(4) Sewage Sludge Site—Region II.
Location:
Latitude—40°22'30"N to 40°25'00"N;
Longitude: 73°41'30"W to 73° 45' 00"W.
Size: 22.7 square kilometers (6.6 square nautical miles).
Depth: 27 meters (90 feet).
Primary Use: Sewage sludge.
Period of Use: Until December 31, 1981.
Restriction: Disposal shall be limited to sewage sludge generated by those permittees holding ocean dumping permits which were in force on January 1, 1979. Disposal of other wastes at this site is not permitted until adequate studies of the probable impacts of those wastes on the site have been completed.

(5) Alternate Sewage Sludge Site—Region II.
Location:
Latitude—40°10'30"N to 40°13'30"N;
Longitude: 72°40'30"W to 72°43'30"W.
Size: 31 square kilometers (9 square nautical miles).
Depth: 55 meters (180 feet).
Primary Use: Sewage sludge.
Period of Use: Until December 31, 1981.
Restriction: Disposal of sewage sludge at this site shall take place only upon a finding by EPA that the existing site cannot safely accommodate any more sewage sludge without endangering public health or degrading coastal water quality. Disposal of other wastes at this site is not permitted until adequate studies of the probable impacts of those wastes on the site have been completed.

(6) San Nicolas Basin Ocean Dumping Site—Region IX.
Location—Latitude and Longitude (northwest corner)—
32°55' north latitude,
119°17' west longitude.
Size—1 square nautical mile.
Depth—400 fathoms (2,400 feet).
Primary use—disposal of formation cuttings, waste drilling mud, and non-perishable solid waste.
Period of use—three years after issuance of an ocean dumping permit for use of this site.

(7) Acid Waste Site—Region II.
Location:
Latitude—40d 16' N. to 40d 20' N.
Longitude—73d 36' W. to 73d 40' W.
Size: 41 square kilometers.
Depth: Ranges from 22.6 meters to 28.3 meters.
Primary Use: Aqueous acid waste (note restriction below).
Period of Use: Continuing use.
Restriction: Aqueous acid wastes are those that are miscible with seawater and will

not form or include a significant solid phase.

(8) South Oahu Site—Region IX.

Location (center point):

Latitude—21°15'10" N.

Longitude—157°56'30" W.

Size: 2 kilometers wide and 2.6 kilometers long.

Depth: Ranges from 400 to 475 meters.

Primary Use: Dredged material.

Period of Use: Continuing use.

Restriction: Disposal shall be limited to dredged material.

(9) Nawiliwili Site—Region IX.

Location (center point):

Latitude—21°55'00" N.

Longitude—159°17'00" W.

Size: Circular with a radius of approximately 920 meters.

Depth: Ranges from 840 to 1,120 meters.

Primary Use: Dredged material.

Period of Use: Continuing use.

Restriction: Disposal shall be limited to dredged material.

(10) Port Allen Site—Region IX.

Location (center point):

Latitude—21°50'00" N.

Longitude—159°35'00" W.

Size: Circular with a radius of approximately 920 meters.

Depth: Ranges from 1,460 to 1,610 meters.

Primary Use: Dredged material.

Period of Use: Continuing use.

Restriction: Disposal shall be limited to dredged material.

(11) Kahului Site—Region IX.

Location (center point):

Latitude—21°04'42" N.

Longitude—156°29'00" W.

Size: Circular with a radius of approximately 920 meters.

Depth: Ranges from 345 to 365 meters.

Primary Use: Dredged material.

Period of Use: Continuing use.

Restriction: Disposal shall be limited to dredged material.

(12) Hilo Site—Region IX.

Location (center point):

Latitude—19°48'30" N.

Longitude—154°58'30" W.

Size: Circular with a radius of approximately 920 meters.

Depth: Ranges from 330 to 340 meters.

Primary Use: Dredged material.

Period of Use: Continuing use.

Restriction: Disposal shall be limited to dredged material.

(13) Cellar Dirt Site—Region II.

Location (center point):

Latitude—40° 23' 00" N.

Longitude—73' 49' 00" W.

Size: 1.1 square nautical miles.

Depth: Ranges from 29 to 38 meters.

Primary Use: Cellar dirt.

Period of Use: Continuing use.

Restriction: Disposal shall be limited to excavation dirt and rock, broken concrete, rubble, tile, and other nonfloatable debris.

(14) Tampa Harbor Site 4—Region IV.

Location:

27°32'27"N., 83°03'46"W.;

27°30'27"N., 83°03'46"W.;

27°30'27"N., 83°06'02"W;

27°32'27"N., 83°06'02"W.

Size: 4 nautical square miles.

Depth: Ranges from 21.8 to 24.1 meters.

Primary Use: Dredged material.

Period of Use: Three years.

Restrictions: Disposal shall be limited to dredged material from the Tampa Harbor Project.

(15) New York Bight Dredged Material Disposal Site—Region II.

Location:

40°23'48" N., 73°51'28" W.;

40°21'48" N., 73°50'00" W.;

40°21'48" N., 73°51'28" W.;

40°23'48" N., 73°50'00" W.

Size: 2.2 square nautical miles.

Depth: Ranges from 16 to 29 meters.

Use Restricted to Disposal of: Dredged materials.

Period of Use: Continuing use, subject to volumetric restriction as noted below.

Restriction: Disposal shall be limited to 100 million cubic yards of dredged materials generated in the Port of New York and New Jersey and nearby harbors. Dumping within the area described by the following coordinates shall be limited to projects determined by the Corps and EPA to demonstrate a specific need, such as research or final capping. 40°23'48" N., 73°51'28" W.; 40°23'23" N., 73°51'28" W.; 40°23'23" N., 73°51'06" W.; 40°23'48" N., 73°51'06" W. Dumping in the southeast quadrant of the site shall not be authorized except as part of a research project on capping.

(16) Gulf of Mexico Platform Jacket site—Region VI.

Location:

27d 39'44.665" N, 91d 10'03.059" W;

27d 39'42.304" N, 91d 07'06.927" W;

27d 37'05.471" N, 91d 07'09.610" W;

27d 37'07.828" N, 91d 10'05.672" W.

Size: 3 statute miles on the side (9 square statute miles total area).

Depth: 600 fathoms.

Primary Use: One-time disposal of damaged platform jacket. Period of Use: Until the one-time dump of the damaged jacket is concluded; however, the period of use shall not exceed three years from the date of publication of this Notice.

(17) Deepwater Industrial Wastes Dump Site—Region II.

Location (center point):

Latitude—38°45'00"N.

Longitude—72°20'00"W.

Size: Circular with a radius of 3.0 nautical miles—28.3 square nautical miles.

Depth: Ranges from 2.250 to 2.750 meters.
Use Restricted To: Aqueous industrial materials.
Period of Use: Continuing use.
Definition: Aqueous industrial materials are defined as those wastes generated by a manufacturing or processing plant (i) with solid concentrations sufficiently low so that waste material is dispersed within the upper water column: or (ii) neutrally buoyant or slightly denser than seawater, such that, upon mixing with seawater, the material does not float.
(18) Deepwater Municipal Sludge Dump Site—Region II.
Location:
Latitude—38°40'00" to 39°00'00"N:
Longitude—72°00'00" to 72°05'00"W.
Size: 100 square nautical miles.
Depth: Ranges from 2.250 to 2.750 meters.
Use Restricted To: Municipal sewage treatment sludge.
Period of Use: Five years after commencement of dumping of municipal sewage treatment sludge at the site.
Restriction: Municipal sludges generated at Publicly Owned or Operated Treatment Works (POTW's). Biologically treated industrial waste sludges are to be excluded.
(19) Jacksonville Dredged Material Site—Region IV.
Location:
30°21'30" N., 81°18'34" W.;
30°21'30" N., 81°17'26" W.;
30°20'30" N., 81°17'26" W.;
30°20'30" N., 81°18'34" W.
Size: One square nautical mile.
Depth: Ranges from 12 to 16 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Jacksonville, Florida, area.
(20) Galveston Dredged Material Site—Region VI.
Location:
29°18'00" N., 94°39'30" W.;
29°15'54" N., 94°37'06" W.;
29°14'24" N., 94°38'42" W.;
29°16'54" N., 94°41'30" W.
Size: 6.6. square nautical miles.
Depth: Ranges from 10 to 15.5 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Galveston, Texas, area.
(21) Drilling muds and cuttings site—Region IX.
Center point location: 33°34'30" N latitude, 118°27'30" W longitude.
Size: A circle with a diameter of 3.0 nautical miles.
Depth: Approximately 485 fathoms (2910 feet).
Primary Use: Drilling muds and cuttings.
Period of Use: 3 years from effective date of site designation.
Volumes: To be determined by EPA Regional Administrator, Region IX.
Restriction: Disposal shall be limited to water-based drilling muds and cuttings which meet the requirements of the Ocean Dumping Evaluation Criteria of 40 CFR Part 227. Permittee(s) must implement monitoring program acceptable to EPA Regional Administrator responsible for management of the site.
(22) San Francisco Channel Bar Dredged Material Site—Region IX.
Location:
37°44'55" N. 122°37'18" W:
37°45'45" N. 122°34'24" W:
37°44'24" N. 122°37'06" W:
37°45'15" N. 122°34'12" W.
Size: 4,572 x 914 meters.
Depth: Ranges from 11 to 14.3 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to material from required dredging operations at the entrance of the San Francisco main ship channel which is composed primarily of sand having grain sizes compatible with naturally occurring sediments at the disposal site and containing approximately 5 percent of particles having grain sizes finer than that normally attributed to very fine sand (.075 millimeters). Other dredged materials meeting the requirements of 40 CFR 227.13 but having smaller grain sizes may be dumped at this site only upon completion of an appropriate case-by-case evaluation of the impact of such material on the site which demonstrates that such impact will be acceptable.
(23) Mouth of Columbia River Dredged Material Site A—Region X.
Location:
46d 13' 03" N., 124d 06' 17" W.;
46d 12' 50" N., 124d 05' 55" W.;
46d 12' 13" N., 124d 06' 43" W.;
46d 12' 26" N, 124d 07' 05" W.
Size: 0.27 square nautical miles.
Depth: Ranges from 14–25 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.
(24) Mouth of Columbia River Dredged Material Site B—Region X.
Location:
46d 14' 37" N., 124d 10' 34" W.;
46d 13' 53" N., 124d 10' 01" W.;
46d 13' 43" N., 124d 10' 26" W.;
46d 14' 28" N., 124d 10' 59" W.
Size: 0.25 square nautical miles.
Depth: Ranges from 24–39 meters.
Primary Use: Dredged material.

Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(25) Mouth of Columbia River Dredged Material Site E—Region X.
Location:
46d 15' 43" N., 124d 05' 21" W.;
46d 15' 36" N., 124d 05' 11" W.;
46d 15' 11" N., 124d 05' 53" W.;
46d 15' 18" N., 124d 06' 03" W.
Size: 0.08 square nautical miles.
Depth: Ranges from 16-21 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(26) Mouth of Columbia River Dredged Material Site F—Region X.
Location:
46d 12' 12" N., 124d 09' 00" W.;
46d 12' 00" N., 124d 08' 42" W.;
46d 11' 48" N., 124d 09' 00" W.;
46d 12' 00" N., 124d 09' 18" W.
Size: 0.08 square nautical miles.
Depth: Ranges from 38-42 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Columbia River entrance channel and adjacent areas.

(27) Coos Bay Dredged Material Site E—Region X.
Location:
43d 21' 59" N., 124d 22' 45" W.;
43d 21' 48" N., 124d 21' 59" W.;
43d 21' 35" N., 124d 22' 05" W.;
43d 21' 46" N, 124d 22' 51" W.
Size: 0.13 square nautical mile.
Depth: Averages 17 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material in the Coos Bay area of type 1, as defined in the site designation final EIS.

(28) Coos Bay Dredged Material Site F—Region X.
Location:
43d 22' 44" N., 124d 22' 18" W.;
43d 22' 29" N., 124d 21' 34" W.;
43d 22' 16" N., 124d 21' 42" W.;
43d 22' 31" N., 124d 22' 26" W.
Size: 0.13 square nautical mile.
Depth: Averages 24 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material in the Coos Bay area of type 1, as defined in the site designation final EIS.

(29) Coos Bay Dredged Material Site H—Region X.
Location:
43d 23' 53" N., 124d 22' 48" W.;
43d 23' 42" N., 124d 23' 01" W.;
43d 24' 16" N., 124d 23' 26" W.;
43d 24' 05" N., 124d 23' 38" W.
Size: 0.13 square nautical mile.
Depth: Averages 55 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material in the Coos Bay area of type 2 and 3, as defined in the site designation final EIS.

(30) Fernandina Beach, Florida Dredged Material Disposal Site—Region IV.
Location:
30°33'00" N.; 81°16'52"W.
30°31'00" N.; 81°16'52" W.
30°31'00" N.; 81°19'08" W.
30°33'00" N.; 81°19'08" W.
Size: 4 square nautical miles
Depth: Average 16 meters
Primary use: Dredged Material
Period of Use: Continuing use
Restrictions: Disposal shall be limited to dredged material which meets the criteria given in the Ocean Dumping Regulations, Part 227.

(31) Morehead City, North Carolina, Dredged Material Disposal Site-Region IV.
Location:
34°38'30" N., 76°45'0" W.;
34°38'30" N., 76°41'42" W.;
34°38'09" N., 76°41'0" W;
34°36'0" N., 76°41'0" W., 34°36'0" N., 76°45'0" W.
Size: 8 square nautical miles.
Depth: Average 12.0 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Morehead City Harbor, North Carolina area. All material disposed must satisfy the requirements of the ocean dumping regulations.

(32) Savannah, GA, Dredged Material Disposal Site—Region IV.
Location:
31d, 55' 53"N., 80d 44' 20"W.;
31d 57' 55"N., 80d 46' 48"W.;
31d 57' 55"N., 80d 44' 20"W.;
31d 55' 53"N., 80d 46' 48"W.
Size: 4.26 square nautical miles.
Depth: Averages 11.4 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Savannah Harbor area.

(33) Charleston, SC, Dredged Material Disposal Site—Region IV.
Location:
32d 40' 27"N., 79d 47' 22"W.;
32d 39' 04"N., 79d 44' 25"W.;
32d 38' 07"N., 79d 45' 03"W.;

32d 39' 30"N., 79d 48' 00"W.
Size: 3 square nautical miles.
Depth: Averages 11 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the Charleston Harbor area.

(34) Charleston, SC, Harbor Deepening Project Dredged Material Disposal Site—Region IV.
Location:
32d 38' 06"N., 79d 41' 57"W.;
32d 40' 42"N., 79d 47' 30"W.;
32d 39' 04"N., 79d 49' 21"W.;
32d 36' 28"N., 79d 43' 48"W.
Size: 11.8 square nautical miles.
Depth: Averages 11 meters.
Primary Use: Dredged material from the Charleston Harbor deepening project.
Period of Use: Not to exceed seven years from the initiation of the Charleston Harbor deepening project.
Restriction: Disposal shall be limited to dredged material from the Charleston Harbor deepening project.

(35) Wilmington, NC, Dredged Material Disposal Site—Region IV.
Location:
33d 49' 30"N., 78d 03' 06"W.;
33d 48' 18"N., 78d 01' 39"W.;
33d 47' 19"N., 78d 02' 48"W.;
33d 48' 30"N., 78d 04' 16"W.
Size: 2.3 square nautical miles.
Depth: Averages 13 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from Wilmington Harbor area.

(36)—(41) [Reserved]

(42) Sabine-Neches Dredged Material Site 1—Region VI.
Location:
29°28'03" N., 93°41'14" W.;
29°26'11" N., 93°41' 14" W.;
29°26'11" N., 93°44'11" W.
Size: 2.4 square nautical miles.
Depth: Ranges from 11-13 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(43) Sabine-Neches Dredged Material Site 2—Region VI.
Location:
29°30'41" N., 93°43'49" W.;
29°28'42" N., 93°41'33" W.;
29°28'42" N., 93°44'49" W.;
29°30'08" N., 93°46'27" W.
Size: 4.2 square nautical miles.
Depth: Ranges from 9-13 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(44) Sabine-Neches Dredged Material Site 3—Region VI.
Location:
29°34'24" N., 93°48'13" W.;
29°32'47" N., 93°46'16" W.;
29°32'06" N., 93°46'29" W.;
29°31'42" N., 93°48'16" W.;
29°32'59" N., 93°49'48" W.
Size: 4.7 square nautical miles.
Depth: 10 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(45) Sabine-Neches Dredged Material Site 4—Region VI.
Location:
29°38'09" N., 93°49'23" W.;
29°35'53" N., 93°48'18" W.;
29°35'06" N., 93°50'24" W.;
29°36'37" N., 93°51'09" W.;
29°37'00" N., 93°50'06" W.;
29°37'46" N., 93°50'26" W.
Size: 4.2 square nautical miles.
Depth: Ranges from 5-9 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restriction: Disposal shall be limited to dredged material from the Sabine-Neches area.

(46) [Reserved]

(47) Portland, Maine, Dredged Material Disposal Site—Region 1
Location:
43°33'36" N, 70°02'42" W;
43°33'36" N, 70°01'18" W;
43°34'36" N, 70°02'42" W;
43°34'36" N, 70°01'18" W;
Size: 1 square nautical mile.
Depth: 50 meters.
Primary Use: Dredged material.
Period of Use: Continuing Use.
Restrictions: Disposal shall be limited to dredged material.

(48) Pensacola, Florida Dredged Material Disposal Site—Region IV.
Location:
30°17'24" N., 87°18'30" W.
30°17'00" N., 87°19'50" W.
30°15'36" N., 87°17'48" W.
30°15'15" N., 87°19'18" W.
Size: 2.48 nmi^2.
Depth: Average 11 m.
Primary use: Dredged Material.
Period of use: Continuing use.
Restrictions: Disposal shall be limited to dredged materials which are shown to be predominantly sand (defined by median grain size greater than 0.125 mm and a composition of less than 10% fines) and meet the Ocean Dumping Criteria.

(49) Mobile, Alabama Dredged Material Disposal Site—Region IV.
Location:
30°10'00" N., 88°07'42" W.
30°10'24" N., 88°05'12" W.
30°09'24" N., 88°04'42" W.
30°08'30" N., 88°05'12" W.
30°08'30" N., 88°08'12" W.
Size: 4.8 nmi².
Depth: Average 14 m.
Primary use: Dredged materials.
Period of use: Continuing use.
Restrictions: Disposal shall be limited to dredged materials which meet the Ocean Dumping Criteria.
(50) Gulfport, Mississippi Dredged Material Disposal Sites—Region IV.
Location: Eastern Site
30°11'10" N., 88°58'24" W.
30°11'12" N., 88°57'30" W.
30°07'36" N., 88°54'24" W.
30°07'24" N., 88°54'48" W.
Western Site
30°12'00" N., 89°00'30" W.
30°12'00" N., 88°59'30" W.
30°11'00" N., 89°00'00" W.
30°07'00" N., 88°56'30" W.
30°06'36" N., 88°57'00" W.
30°10'30" N., 89°00'36" W.
Size: Eastern—2.47 nmi², Western—5.2 nmi².
Depth: Eastern—9.1 m. Western—8.2 m.
Primary use: Both sites—Dredged material.
Period of use: Both sites—Continuing use.
Restrictions: Disposal shall be limited to dredged materials which meet the Ocean Dumping Criteria.
(51) Calcasieu Dredged Material Site 1—Region VI.
Location:
29d 45' 39" N, 93d 19' 36" W;
29d 42' 42" N, 93d 19' 06" W;
29d 42' 36" N, 93d 19" 48" W;
29d 44' 42" N, 93d 20' 12" W;
29d 44' 42" N, 93d 20' 24" W;
29d 45' 27" N, 93d 20' 33" W.
Size: 1.76 square nautical miles
Depth: Ranges from 2-8 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the vicinity of the Calcasieu River and Pass Project.
(52) Calcasieu Dredged Material Site 2—Region VI.
Location:
29d 44' 31" N, 93d 20' 43" W;
29d 39' 45" N, 93d 19' 56" W;
29d 39' 34" N, 93d 20' 46" W;
29d 44' 25" N, 93d 21' 33" W.
Size: 3.53 square nautical miles.
Depth: Ranges from 2-11 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the vicinity of the Calcasieu River and Pass Project.
(53) Calcasieu Dredged Material Site 3—Region VI.
Location:
29d 37' 50" N, 93d 19' 37" W;
29d 37' 25" N, 93d 19' 33" W;
29d 33' 55" N, 93d 16" 23" W;
29d 33' 49" N, 93d 16" 25" W;
29d 30' 59" N, 93d 13' 51" W;
29d 29' 10" N, 93d 13' 49" W;
29d 29' 05" N, 93d 14' 23" W;
29d 30' 49" N, 93d 14' 25" W;
29d 37' 26" N, 93d 20' 24" W;
29d 37' 44" N, 93d 20' 27" W.
Size: 5.88 square nautical miles.
Depth: Ranges from 11-14 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the vicinity of the Calcasieu River and Pass Project.
(54) San Juan Harbor, PR Dredged Material Site—Region II
Location:
18d 30'10" N", 66d 09'31" W";
18d 30'10" N", 66d 08'29" W";
18d 31'10" N", 66d 08'29" W";
18d 31'10" N", 66d 09'31" W".
Size: 0.98 square nautical miles.
Depth: Ranges from 200-400 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredge material from the Port of San Juan, Puerto Rico, and coastal areas within 20 miles of said port entrance.
(55) Dam Neck, Virginia, Dredged Material Disposal Site—Region III.
Location:
36°51'24.1" N., 75°54'41.4" W.;
36°51'24.1" N., 75°53'02.9" W.;
36°50'52.0" N., 75°52'49.0" W.;
36°46'27.4" N., 75°51'39.2" W.;
36°46'27.5" N., 75°54'19.0" W.;
36°50'05.0" N., 75°54'19.0" W.
Size: 8 square nautical miles.
Depth: Averages 11 meters.
Primary Use: Dredged material.
Period of Use: Continuing use.
Restriction: Disposal shall be limited to dredged material from the mouth of the Chesapeake Bay.

[42 FR 2482, Jan. 11, 1977]

EDITORIAL NOTES: 1. For FEDERAL REGISTER citations affecting § 228.12, see the List of CFR Sections Affected in the Finding Aids section of this volume.

2. At 53 FR 6990, Mar. 4, 1988, § 228.12 was amended by adding paragraphs (b)(48), (b)(49) and (b)(50) and at 53 FR 8185, Mar. 14, 1988, paragraphs designated (b)(48), (b)(49) and (b)(50) were added again. The paragraphs added in the March 14, 1988 document appear above as newly added paragraphs (b)(51), (b)(52) and (b)(53). The

Enviromental Protection Agency will publish a correction document in the FEDERAL REGISTER at a later date.

3. The following interim dredged material sites became approved ocean dumping sites when EPA published final rules in the FEDERAL REGISTER. These sites, formerly found in paragraph (a), are now found in paragraph (b) of § 228.12:

Interim site	Paragraph
Morehead City, NC	(a)(1)(i)
Portland, ME	(a)(1)(ii), (a)(3)
San Juan, PR	(a)(1)(ii), (a)(3)
Charleston/Savannah/Wilmington	(a)(1)(ii), (a)(3)
Mouth of Columbia River, OR	(a)(1)(ii), (a)(3)
Gulfport, MS/Mobile, AL/Pensacola, FL	(a)(3)
Sabine Neches Waterway, TX	(a)(3)

At a later date, EPA will publish documents in the FEDERAL REGISTER corredtly removing these interim sites from paragraph (a).

§ 228.13 *Guidelines for ocean disposal site baseline or trend assessment surveys under section 102 of the Act.*

The purpose of a baseline or trend assessment survey is to determine the physical, chemical, geological, and biological structure of a proposed or existing disposal site at the time of the survey. A baseline or trend assessment survey is to be regarded as a comprehensive synoptic and representative picture of existing conditions; each such survey is to be planned as part of a continual monitoring program through which changes in conditions at a disposal site can be documented and assessed. Surveys will be planned in coordination with the ongoing programs of NOAA and other Federal, State, local, or private agencies with missions in the marine environment. The field survey data collection phase of a disposal site evaluation or designation study shall be planned and conducted to obtain a body of information both representative of the site at the time of study and obtained by techniques reproducible in precision and accuracy in future studies. A full plan of study which will provide a record of sampling, analytical, and data reduction procedures must be developed, documented and approved by the EPA management authority. Plans for all surveys which will produce information to be used in the preparation of environmental impact statements will be approved by the Administrator or his designee. This plan of study also shall be incorporated as an appendix into a technical report on the study, together with notations describing deviations from the plan required in actual operations. Relative emphasis on individual aspects of the environment at each site will depend on the type of wastes disposed of at the site and the manner in which such wastes are likely to affect the local environment, but no major feature of the disposal site may be neglected. The observations made and the data obtained are to be based on the information necessary to evaluate the site for ocean dumping. The parameters measured will be those indicative, either directly or indirectly, of the immediate and long-term impact of pollutants on the environment at the disposal site and adjacent land or water areas. An initial disposal site evaluation or designation study should provide an immediate baseline appraisal of a particular site, but it should also be regarded as the first of a series of studies to be continued as long as the site is used for waste disposal.

(a) *Timing.* Baseline or trend assessment surveys will be conducted with due regard for climatic and seasonal impact on stratification and other conditions in the upper layers of the water column. Where a choice of season is feasible, trend assessment surveys should be made during those months when pollutant accumulation within disposal sites is likely to be most severe, or when pollutant impact within disposal sites is likely to be most noticeable.

(1) Where disposal sites are near large riverine inflows to the ocean, surveys will be done with due regard for the seasonal variation in river flow. In some cases several surveys at various river flows may be necessary before a site can be approved.

(2) When initial surveys show that seasonal variation is not significant and surveys at greater than seasonable intervals are adequate for characterizing a site, resurveys shall be carried out in climatic conditions as similar to those of the original surveys as possible, particularly in depths less than 200 meters.

(b) *Duration.* The actual duration of a field survey will depend upon the size and depth of the site, weather conditions during the survey, and the types of data to be collected. For example, for a survey of an area of 100 square miles on the continental shelf, including an average dump site and the region contiguous to it, an on-site operation would be scheduled for completion within one week of weather suitable for on-site operations. More on-site operating time may be scheduled for larger or highly complex sites.

(c) *Numbers and locations of sampling stations.* The numbers and locations of sampling stations will depend in part on the local bathymetry with minimum numbers of stations per site fixed as specified in the following sections. Where the bottom is smooth or evenly sloping, stations for water column measurements and benthic sampling and collections, other than trawls, shall be spaced throughout the survey area in a manner planned to provide maximum coverage of both the disposal site and contiguous control areas, considering known water movement characteristics. Where there are major irregularities in the bottom topography, such as canyons or gullies, or in the nature of the bottom, sampling stations for sediments and benthic communities shall be spaced to provide representative sampling of the major different features.

Sampling shall be done within the dump site itself and in the contiguous area. Sufficient control stations outside a disposal site shall be occupied to characterize the control area environment at least as well as the disposal site itself. Where there are known persistent currents, sampling in contiguous areas shall include at least two stations downcurrent of the dump site, and at least two stations upcurrent of the site.

(d) *Measurements in the water column at and near the dump site*—(1) *Water quality parameters measured.* These shall include the major indicators of water quality, particularly those likely to be affected by the waste proposed to be dumped. Specifically included at all stations are measurements of temperature, dissolved oxygen, salinity, suspended solids, turbidity, total organic carbon, pH, inorganic nutrients, and chlorophyll *a*.

(i) At one station near the center of the disposal site, samples of the water column shall be taken for the analysis of the following parameters: Mercury, cadmium, copper, chromium, zinc, lead, arsenic, selenium, vanadium, beryllium, nickel, pesticides, petroleum hydrocarbons, and persistent organohalogens. These samples shall be preserved for subsequent analysis by or under the direct supervision of EPA laboratories in accordance with the approved plan of study.

(ii) These parameters are the basic requirements for all sites. For the evaluation of any specific disposal site additional measurements may be required, depending on the present or intended use of the site. Additional parameters may be selected based on the materials likely to be in wastes dumped at the site, and on parameters likely to be affected by constituents of such wastes. Analysis for other constituents characteristic of wastes discharged to a particular disposal site, or of the impact of such wastes on water quality, will be included in accordance with the approved plan of study.

(2) *Water quality sampling requirements.* The number of samples collected from the water column should be sufficient to identify representative changes throughout the water column such as to avoid short-term impact due to disposal activities. The following key locations should be considered in selecting water column depths for sampling:

(i) Surface, below interference from surface waves;

(ii) Middle of the surface layer;

(iii) Bottom of the surface layer;

(iv) Middle of the thermocline or halocline, or both if present;

(v) Near the top of the stable layer beneath a thermocline or halocline;

(vi) Near the middle of a stable layer;

(vii) As near the bottom as feasible;

(viii) Near the center of any zone showing pronounced biological activity or lack thereof.

In very shallow waters where only a few of these would be pertinent, as a

minimum, surface, mid-depth and bottom samples shall be taken, with samples at additional depths being added as indicated by local conditions. At disposal sites far enough away from the influence of major river inflows, ocean or coastal currents, or other features which might cause local perturbations in water chemistry, a minimum of 5 water chemistry stations should be occupied within the boundaries of a site. Additional stations should be added when the area to be covered in the survey is more than 20 square miles or when local perturbations in water chemistry may be expected because of the presence of one of the features mentioned above. In zones where such impacts are likely, stations shall be distributed so that at least 3 stations are occupied in the transition from one stable regime to another. Each water column chemistry station shall be replicated a minimum of 2 times during a survey except in waters over 200 meters deep.

(3) *Water column biota.* Sampling stations for the biota in the water column shall be as near as feasible to stations used for water quality; in addition at least two night-time stations in the disposal site and contiguous area are required. At each station vertical or oblique tows with appropriately-meshed nets shall be used to assess the microzooplankton, the nekton, and the macrozooplankton. Towing times and distances shall be sufficient to obtain representative samples of organisms near water quality stations. Organisms shall be sorted and identified to taxonomic levels necessary to identify dominant organisms, sensitive or indicator organisms, and organism diversity. Tissue samples of representative species shall be analyzed for pesticides, persistent organohalogens, and heavy metals. Discrete water samples shall also be used to quantitatively assess the phytoplankton at each station.

These requirements are the minimum necessary in all cases. Where there are discontinuities present, such as thermoclines, haloclines, convergences, or upwelling, additional tows shall be made in each water mass as appropriate.

(e) *Measurements of the benthic region*—(1) *Bottom sampling.* Samples of the bottom shall be taken for both sediment composition and structure, and to determine the nature and numbers of benthic biota.

(i) At each station sampling may consist of core samples, grab samples, dredge samples, trawls, and bottom photography or television, where available and feasible, depending on the nature of the bottom and the type of disposal site. Each type of sampling shall be replicated sufficiently to obtain a representative set of samples. The minimum numbers of replicates of successful samples at each continental shelf station for each type of device mentioned above are as follows:

Cores	3.
Grabs	5.
Dredge	3.
Trawl	20-min. tow.

Lesser numbers of replicates may be allowed in water deeper than 200 meters, at those sites where pollution impacts on the bottom are unlikely in the judgment of the EPA management authority.

(ii) Selection of bottom stations will be based to a large extent on the bottom topography and hydrography as determined by the bathymetric survey. On the continental shelf, where the bottom has no significant discontinuities, a bottom station density of at least three times the water column stations is recommended, depending on the type of site being evaluated. Where there are significant differences in bottom topography, additional stations shall be occupied near the discontinuity and on each side of it. Beyond the continental shelf, lesser densities may be used.

(2) *Bathymetric survey.* Sufficient tracklines shall be run to develop complete bottom coverage of bathymetry with reasonable assurance of accurate coverage of bottom topography, with trackline direction and spacing as close as available control allows. The site itself is to be developed at the greatest density possible, with data to be collected to a suitable distance about the site as is required to identify major changes in bathymetry which might

affect the site. Specifications for each bathymetric survey will vary, depending on control, bottom complexity, depths, equipment, and map scale required. In most cases, a bathymetric map at a scale of 1:25,000 to 1:10,000 will be required, with a minimum of 1-5 meter contour interval except in very flat areas. When the foregoing bathymetric detail is available from recent surveys of the disposal site, bathymetry during a baseline or trend assessment survey may be limited to sonar profiles of bathymetry on transects between sampling stations.

(3) *Nature of bottom.* The size distribution of sediments, mineral character and chemical quality of the bottom will be determined to a depth appropriate for the type of bottom. The following parameters will be measured at all stations: Particle size distribution, major mineral constituents, texture, settling rate, and organic carbon.

(i) At several stations near the center of the disposal site, samples of sediments shall be taken for the analysis of the following parameters: Mercury, cadmium, copper, chromium, zinc, lead, arsenic, selenium, vanadium, beryllium, nickel, pesticides, persistent organohalogens, and petroleum hydrocarbons. These samples shall be preserved for subsequent analysis by or under the direct supervision of EPA laboratories in accordance with the approved plan of study.

(ii) These parameters are the basic requirements for all sites. For the evaluation of any specific disposal site additional measurements may be required, depending on the present or intended use of the site. Additional parameters may be selected based on the materials likely to be in wastes dumped at the site, and on parameters likely to be affected by constituents of such wastes. Such additional parameters will be selected by the EPA management authority.

(4) *Benthic biota.* This shall consist of a quantitative and qualitative evaluation of benthic communities including macroinfauna and macroepifauna, meiobenthos, and microbenthos, and should include an appraisal, based on existing information, of the sensitivity of indigenous species to the waste proposed to be discharged. Organisms shall be sorted, and identified to taxonomic levels necessary to identify dominant organisms, sensitive or indicator organisms, and organism diversity. Tissue samples of the following types of organisms shall be analyzed for persistent organohalogens, pesticides, and heavy metals:

(i) A predominant species of demersal fish;

(ii) The most abundant macroinfaunal species; and

(iii) A dominant epifaunal species, with particular preference for a species of economic importance.

(f) *Other measurements*—(1) *Hydrodynamic features.* The direction and speed of water movement shall be characterized at levels appropriate for the site and type of waste to be dumped. Where depths and climatic conditions are great enough for a thermocline or halocline to exist, the relationship of water movement to such a feature shall be characterized.

(i) *Current measurements.* When current meters are used as the primary source of hydrodynamic data, at least 4 current meter stations with at least 3 meters at depths appropriate for the observed or expected discontinuities in the water column should be operated for as long as possible during the survey. Where feasible, current meters should be deployed at the initiation of the survey and recovered after its completion. Stations should be at least a mile apart, and should be placed along the long axis of the dumping site. For dumping sites more than 10 miles along the long axis, one current meter station every 5 miles should be operated. Where there are discontinuities in surface layers, e.g., due to land runoff, stations should be operated in each water mass.

(ii) *Water mass movement.* Acceptable methods include: dye, drogues, surface drifters, side scan sonar, bottom drifters, and bottom photography or television. When such techniques are the primary source of hydrodynamic data, coverage should be such that all significant hydrodynamic features likely to affect waste movement are measured.

(2) *Sea state.* Observations of sea state and of standard meteorological

parameters shall be made at 8-hour intervals.

(3) *Surface phenomena.* Observations shall be made of oil slicks, floating materials, and other visible evidence of pollution; and, where possible, collections of floating materials shall be made.

(g) *Survey procedures and techniques.* Techniques and procedures used for sampling and analysis shall represent the state-of-the-art in oceanographic survey and analytical practice. Survey plans shall specify the methods to be used and will be subject to approval by EPA.

(h) *Quality assurance.* The EPA management authority may require that certain samples be submitted on a routine basis to EPA laboratories for analysis as well as being analyzed by the surveyor, and that EPA personnel participate in some field surveys.

Appendix B

NUMERICAL MODELS FOR INITIAL-MIXING EVALUATIONS

B1.0 INTRODUCTION

This appendix presents guidance for the use of numerical models for evaluation of mixing as part of the Tier II and Tier III water-column evaluations. The versions of the models in this appendix are a part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS) (Schroeder and Palermo, 1990) and can be run on a personal computer (PC). ADDAMS is an interactive computer-based design and analysis system in the field of dredged-material management. The general goal of the ADDAMS is to provide state-of-the-art computer-based tools that will increase the accuracy, reliability, and cost-effectiveness of dredged-material management activities in a timely manner.

B1.1 MODEL APPLICATIONS

Any evaluation of potential water-column effects has to take into consideration the effects of initial mixing. Section 227.29 defines initial mixing as follows.

> *Initial mixing is defined to be that dispersion or diffusion of liquid, suspended particulate, and solid phases of a waste which occurs within four hours after dumping. The limiting permissible concentration* [LPC] *shall not be exceeded beyond the boundaries of the disposal site during initial mixing, and shall not be exceeded at any point in the marine environment after initial mixing.*

Versions of the models described in this appendix, for use on IBM-compatible microcomputers, are provided on the diskettes in the pocket inside the back cover of this manual. The diskettes contain models appropriate for three types of discharges that may be used for ocean dumping – instantaneous discharges, continuous discharges, and hopper-dredge discharges. The user must select the appropriate model for the particular disposal operation proposed. Each of these three types of discharge model described in this appendix has been designed to evaluate initial mixing for each of the three specific applications described in this manual. As discussed in the remainder of Section B1.1, these applications, which are progressively more precise and should be used sequentially, are

- **Model application for screen to determine WQC compliance in Tier II** – In this application of the model, the dredged material is screened for potential impact by conservatively assuming that all contaminants in the dredged material are available to water-column organisms. This application is based on whole-sediment contaminant concentrations.

- **Model Application for Elutriate Analysis To Determine WQC Compliance in Tier II** – In this application of the model, measured concentrations of contaminants in an elutriate of the dredged material are used to evaluate the potential for water-column impact at the disposal site. The elutriate data provide a more accurate determination of impact than those which can be obtained by using the whole-sediment data that are used in the screen.
- **Model Application for Water-Column Bioassays in Tier III** – In this application of the model, the potential for water-column impact is further described by using the model to relate biological test results to contaminant concentrations that could occur at the disposal site.

B1.1.1 Model Application for Screen to Determine WQC Compliance in Tier II

The evaluation of the potential for water-column impact in Tier II begins with a determination of the necessity of additional water-column testing. This determination is based on a standardized calculation comparing contamination of the dredged material with WQC, considering the effects of initial mixing. The models need be run only for the contaminant requiring the greatest dilution to meet its WQC. It should be noted that contaminant concentration in dredged material usually is expressed in micrograms per kilogram (μg/kg) dry weight. The model uses contaminant concentration in micrograms per liter (μg/L) when calculating the necessary dilution factor for the dredged material (Section 10.1.1). To convert the contaminant concentration reported on a dry-weight basis to the contaminant concentration in the dredged material, the dry-weight concentration must be multiplied by the mass of dredged-material solids per liter of dredged material.

The key parameters derived from the dispersion models are the maximum concentration of the contaminant in the water column outside the boundary of the disposal site during the 4-h initial-mixing period, and the maximum concentration anywhere in the marine environment after the 4-h initial-mixing period. These concentrations are compared with the applicable marine WQC according to the guidance in Section 10.1.1 to determine if additional water-column testing is necessary.

B1.1.2 Model Application for Elutriate Analysis To Determine WQC Compliance in Tier II

If additional water-column testing is necessary, the potential for water-column impact should be evaluated under Tier II by comparing predicted dissolved contaminant concentrations in the standard elutriate (in micrograms per liter) (Section 10.1.2) with the WQC, considering the

effects of initial mixing. The models need be run only for the contaminant requiring the greatest dilution to meet its WQC. The key parameters derived from the models are the maximum dissolved concentration of the contaminant outside the boundary of the disposal site during the 4-h initial-mixing period, and the maximum concentration anywhere in the marine environment after the 4-h initial-mixing period. This concentration is compared to the applicable marine WQC according to the guidance in Section 10.1.2.3 to determine if the discharge is acceptable.

B1.1.3 Model Application for Water-Column Bioassays in Tier III

If there are no WQC for all contaminants of concern or if synergistic effects are suspected, the potential for water-column impact should be evaluated under Tier III by comparison of predicted concentrations of the suspended plus dissolved constituents of the dredged material (in percent) with bioassay results, considering the effects of initial mixing (Section 11.1). For this case, the models calculate the dilution of the dredged material expressed as a percent of the initial concentration. The key parameters derived from the model are the maximum concentration of dredged material in the water column outside the boundary of the disposal site during the 4-h initial-mixing period, and the maximum concentration anywhere in the marine environment after the 4-h initial-mixing period. These concentrations are compared to 0.01 of the LC_{50} as determined by the bioassay tests according to the guidance in Section 11.1.7 to determine if the discharge is acceptable.

B1.2 MODEL DESCRIPTIONS AND LIMITATIONS

The models account for the physical processes determining the short-term fate of dredged material disposed at open-water sites. The models provide estimates of water-column concentrations of dissolved contaminants and suspended sediment and the initial deposition of material on the bottom.

Two of the models were developed by Brandsma and Divoky (1976) under the United States Army Corps of Engineers (USACE) Dredged Material Research Program to handle both instantaneous dumps and continuous discharges. The models were based on work by Koh and Chang (1973). A third model that utilized features of the two earlier models was constructed later to handle a semicontinuous disposal operation from a hopper dredge. These models are known as DIFID (Disposal from an Instantaneous Dump), DIFCD (Disposal from a Continuous Discharge), and DIFHD (Disposal from a Hopper Dredge). Collectively, the models are known

within ADDAMS as the Open Water Disposal (DUMP) Models.

For evaluation of initial mixing for ocean disposal, the models need be run only for the contaminant requiring the greatest dilution to meet its WQC. A data-analysis routine is contained in the models for calculating the required dilutions and determining which contaminant should be modeled.

In all three models, the behavior of the material is assumed to be separated into three phases: (1) convective descent, during which the dump cloud or discharge jet falls under the influence of gravity and the initial momentum of the discharge; (2) dynamic collapse, occurring when the descending cloud or jet either impacts the bottom or arrives at a level of neutral buoyancy where descent is retarded and horizontal spreading dominates; and (3) passive transport and dispersion, commencing when the material transport and spreading are determined more by ambient currents and turbulence than by the dynamics of the disposal operation.

These models simulate movement of the disposed material as it falls through the water column, spreads over the bottom, and finally is transported and diffused by the ambient current. DIFID is designed to simulate the movement of material from an instantaneous dump that falls as a hemispherical cloud. Thus, the total time required for the material to leave the disposal vessel should not be greater than the time required for the material to reach the bottom. DIFCD is designed to compute the movement of material disposed in a continuous fashion at a constant discharge rate. Thus, it can be applied to pipeline disposal operations in which the discharge jet is below the water surface or perhaps to the discharge of material from a single bin of a hopper dredge. If the initial direction of disposal is vertical, either the disposal source has to be moving or the ambient current has to be strong enough to result in a bending of the jet before the bottom is encountered. DIFHD has been constructed to simulate the fate of materials disposed from stationary hopper dredges. Here, the normal mode of disposal is to open first one pair of doors, then another, etc., until the complete dump is made, which normally takes on the order of a few minutes to complete. DIFHD should not be applied to disposal operations that differ significantly from that described above.

In addition, it should be noted that the disposed material is expected to behave as a dense liquid. This will be true only if the material is composed of primarily fine-grained solids. Thus, the models should not be applied to the disposal of purely sandy material. A major limitation of these models is the basic assumption that once solid particles are deposited on the bottom, they remain there. Therefore, the models should be applied only over time frames in which erosion of the newly deposited material is unimportant.

The passive transport and diffusion phase in all three models is handled by allowing material settling from the descent and collapse phases to be stored in small Gaussian clouds. These clouds are then diffused and transported at the end of each time step. Computations on the long-term grid are made only at those times when output is desired.

The use and limitations of the models along with theoretical discussions are presented in detail by Johnson (1990). Additional technical references for the models are provided in the bibliography of this appendix and online in the system. Their review is strongly recommended.

B1.4 MODEL INPUT

Input data for the models are grouped into the following general areas: (1) description of the disposal operation, (2) description of the disposal site, (3) description of the dredged materials, (4) model coefficients, and (5) controls for input, execution, and output.

Ambient conditions include current velocity, density stratification, and water depths over a computational grid. The dredged material is assumed to consist of a number of solid fractions, a fluid component, and conservative contaminants. Each solid fraction has to have a volumetric concentration, a specific gravity, a settling velocity, a void ratio for bottom deposition, and information on whether or not the fraction is cohesive. For initial-mixing calculations, information on initial concentration, background concentration, and WQC for the constituent to be modeled has to be specified. The description of the disposal operations for the DIFID model includes the position of the disposal barge on the grid, the barge velocity, and draft, and volume of dredged material to be dumped. Similar descriptions for hopper dredge and pipeline operations are required for the DIFCD and DIFHD models. Coefficients are required for the models to accurately specify entrainment, settling, drag, dissipation, apparent mass, and density-gradient differences. These coefficients have default values that should be used unless other site-specific information is available. Table B-1 lists the necessary input parameters with their corresponding units. More detailed descriptions and guidance for selection of values for many of the parameters is provided directly online in the system.

B1.5 MODEL OUTPUT

The output starts by echoing the input data and then optionally presenting the time history of the descent and collapse phases. In descent history for the DIFID model, the location of the cloud centroid, the velocity of the cloud centroid, the radius of the hemispherical cloud,

TABLE B-1. MODEL INPUT PARAMETERS

Parameter	Models[a]	Units	Option[b]
Disposal Site Descriptions			
Descriptive title	I,C,H		
Gridpoints (left to right)	I,C,H		
Gridpoints (top to bottom)	I,C,H		
Distance between gridpoints	I,C,H	ft	
Constant water depth	I,C,H	ft	C
Gridpoints depths	I,C,H	ft	V
Points in density profile	I,C,H		
Depth of density point	I,C,H	ft	
Density at profile point	I,C,H	g/c^3	
Bottom slope in *x* direction	I,H	deg	
Bottom slope in *z* direction	I,H	deg	
Site boundary grid locations	I,C,H		
Disposal Operation Descriptions			
Volume of material in barge	I	yd^3	
Discharge flow rate	C,H	ft^3/s	
Radius of discharge	C,H	ft	
Discharge depth	C,H	ft	
Angle of discharge	C	deg	
Vessel course	C	deg	
Vessel speed	C	ft/s	
Barge velocity in *x* direction	I	ft/s	
Barge velocity in *z* direction	I	ft/s	
Barge length	I	ft	
Barge width	I	ft	
Postdisposal depth	I	ft	
Bottom depression length in *x* direction	I,H	ft	Optional
Bottom depression length in *z* direction	I,H	ft	Optional
Bottom depression depth	I,H	ft	Optional
X coordinate of disposal operation	I,C,H	ft	
Z coordinate of disposal operation	I,C,H	ft	
Disposal duration	I,C,H	s	
Time from start of tidal cycle	I,C,H	s	
Number of hopper bins opening together	H		
Distance between bins	H	ft	

(continued)

[a]The use of a parameter in the DIFID, DIFCD, and DIFHD models is indicated in the table by either I, C, or H, respectively.

[b]The use of a parameter for the constant-depth option or variable depth option is indicated in the table by either C or V, respectively. Other optional uses for parameters are so indicated.

TABLE B-1. MODEL INPUT PARAMETERS ***(continued)***

Parameter	Models[a]	Units	Option[b]
Disposal Site Velocity Descriptions			
Type of velocity profile	I,C,H		
Tidal cycle time of velocity if constant profile not used	I,C,H	s	V
Vertically averaged velocity in *x* direction at gridpoints	I,C,H	ft/s	V
Vertically averaged velocity in *z* direction at gridpoints	I,C,H	ft/s	V
Velocity in *x* direction at upper point	I,C,H	ft/s	C
Depth of upper point for *x* direction velocity	I,C,H	ft	C
Velocity in *x* direction at lower point	I,C,H	ft/s	C
Depth of lower point for *x* direction velocity	I,C,H	ft	C
Velocity in *z* direction at upper point	I,C,H	ft/s	C
Depth of upper point for *z* direction velocity	I,C,H	ft	C
Velocity in *z* direction at lower point	I,C,H	ft/s	C
Depth of lower point for *z* direction velocity	I,C,H	ft	C
Material Descriptions			
Water density at dredging site	I,C,H	g/c^3	
Number of solid fractions	I,C,H		
Solid-fraction descriptions	I,C,H		
Solid-fraction specific gravity	I,C,H		
Solid-fraction volumetric concentration	I,C,H	ft^3/ft^3	
Solid-fraction settling velocity	I,C,H	ft/s	
Solid-fraction deposited void ratio	I,C,H		
Moisture content of material in barge as multiple of liquid limit	I		Cohesive
Bulk density of dredged material	I,C,H	g/c^3	
Dissolved contaminant concentration	I,C,H	mg/L	Optional
Background dissolved contaminant concentration	I,C,H	mg/L	Optional
Sediment contaminant concentration	I,C,H	mg/kg	Optional
Contaminant water-quality criterion	I,C,H	mg/L	Optional
0.01 of the acutely toxic concentration (LC_{50})	I,C,H	%	Optional

(continued)

[a]The use of a parameter in the DIFID, DIFCD, and DIFHD models is indicated in the table by either I, C, or H, respectively.

[b]The use of a parameter for the constant-depth option or variable-depth option is indicated in the table by either C or V, respectively. Other optional uses for parameters are so indicated.

TABLE B-1. MODEL INPUT PARAMETERS *(continued)*

Parameter	Models[a]	Units	Option[b]
Model coefficient			
Settling coefficient	I,C,H		
Apparent mass coefficient	I,C,H		
Drag coefficient	I,C,H		
Form drag for collapsing cloud	I,C,H		
Skin friction for collapsing cloud	I,C,H		
Drag for an ellipsoidal wedge	I,C,H		
Drag for a plate	I,C,H		
Friction between cloud and bottom	I,C,H		
Horizontal diffusion coefficient	I,C,H		
Cloud/ambient density gradient ratio	I,C,H		
Turbulent thermal entrainment	I,H		
Entrainment in collapse	I,H		
Jet entrainment	H,C		
Thermal entrainment	H,C		
Entrainment by convection in collapse	C		
Entrainment due collapse of element	C		
Input, Output, and Execution Descriptions			
Processes to simulate	I,C,H		
Type of computations to perform for initial mixing	I,C,H		
Number of depths for initial-mixing calculations	I,C,H		
Depths for initial-mixing calculations	I,C,H	ft	
Duration of simulation	I,C,H	s	
Time steps for initial-mixing calculations	I,C,H		
Convective descent output option	I,C,H		
Collapse phase output option	I,C,H		
Number of print times for initial-mixing output	I,C,H		

[a]The use of a parameter in the DIFID, DIFCD, and DIFHD models is indicated in the table by either I, C, or H, respectively.

[b]The use of a parameter for the constant-depth option or variable-depth option is indicated in the table by either C or V, respectively. Other optional uses for parameters are so indicated.

the density difference between the cloud and the ambient water, the conservative constituent concentration and the total volume and concentration of each solid fraction are provided as functions of time since release of the material. Likewise, the location of the leading edge of the momentum jet, the centerline velocity of the jet, the radius of the jet, the density difference between material in the jet and the ambient water, the contaminant concentration, and the flux and concentration of each solid fraction are provided as functions of time at the end of the jetconvection phase in DIFCD and DIFHD.

At the conclusion of the collapse phase in DIFID and DIFHD, time-dependent information concerning the size of the collapsing cloud, its density, and its centroid location and velocity as well as contaminant and solids concentrations can be requested. Similar information is provided by DIFCD at the conclusion of the jet-collapse phase. These models perform the numerical integrations of the governing conservation equations in the descent and collapse phases with a minimum of user input. Various control parameters that give the user insight into the behavior of these computations are printed before the output discussed above is provided.

At various times, as requested through input data, output concerning suspended sediment concentrations can be obtained from the transport-diffusion computations. With Gaussian cloud transport and diffusion, only concentrations at the water depths requested are provided at each grid point.

For evaluations of initial mixing for ocean disposal, results for water-column concentrations can be computed in terms of milligrams per liter of dissolved constituent for Tier II evaluations or in percent of initial concentration of suspended plus dissolved constituents in the dredged material for Tier III evaluations. The maximum concentration within the grid and the maximum concentration at or outside the boundary of the disposal site are tabulated for specified time intervals. Graphics showing the maximum concentrations inside the disposal-site boundary and anywhere on the grid as a function of time can also be generated.

B1.6 GENERAL INSTRUCTIONS FOR RUNNING THE MODELS

B1.6.1 Target Hardware Environment

The system is designed for the IBM PC-AT (including compatibles) class of personal computers. This does not constitute official endorsement or approval of these commercial products. In general, the system requires a mathematics coprocessor, 640 kb of RAM and a hard disk. The models are written primarily in Fortran 77 but some of the higher-level operations and file-

management operations are written in BASIC and some of the screen control operations in the Fortran 77 programs are performed using an Assembly language utility program.

B1.6.2 Installation and Starting

All files contained on the diskettes in the folder in the back of this manual should be saved in a directory on the hard disk dedicated for the ADDAMS system, e.g. C:\ADDAMS. The files are archived on the diskettes and have to be dearchived prior to running the models. To dearchive the files, copy the files from each diskette onto the hard drive, call up the README file, and follow the instructions.

B1.6.3 User Interface

The models in the DUMP application of ADDAMS employ a menu-driven environment with a full-screen data-entry method. In general, single keystrokes (usually the F1 through F10 function keys, the number keys, Esc key or the arrow keys and the Enter key) are required to select menu options in the system. Menus are displayed on the screen. Cursor keys are used to select from among highlighted input fields (displayed in reverse video) much like a spreadsheet program. To enter alphanumeric data, the user moves the cursor to the cell of interest, using the up and down arrows to move, respectively, up and down, the Tab and Shift-Tab keys to move, respectively, right and left. The Enter key is also used to move forward through the cells. The left and right arrow keys are used to move the cursor within a selected cell to edit the cell's contents. The Backspace key is used to delete a single character in a cell. The Delete and Insert keys are used to delete and insert a row of data on a screen of tabular data. Using the PgDn key causes the cursor to move to the next data-entry screen and the PgUp key to move to the previous data-entry screen. The Esc key permits the user to quit data entry on the present operation and to exit to the previous menu. The Home key permits the user to exit from the current data-entry screen to the Main Menu for the application, without loss of data. Results from computations are generally displayed in tabular format on the screen and/or written to print files or devices.

B1.7 STEPS IN USING THE MODEL

The basic steps to follow in applying the models within their menu-driven environment are illustrated in Figure B-1. The general steps and the corresponding menus used in applying the model for a disposal operation are as follows.

a. Starting. Change the directory to make the ADDAMS directory the default directory. Start the program by entering ADDAMS at the prompt. The program will display first the ADDAMS logo and then an Application Selection Menu. An application in the ADDAMS software consists of one or more standalone computer programs or numerical models for performing a specific analysis. The only ADDAMS application provided on diskette with this manual is named DUMP. DUMP consists of programs for evaluating open-water disposal of dredged material. Select the DUMP application from the Application Selection Menu. This causes the program to display a File Manager Menu for the DUMP application input data files.

b. File manager menu. At this point, an input data file or DOS path for data storage may be selected or named. An existing input data file may be selected by displaying a directory of data files on the specified DOS path. Other file-management operations may also be performed on input data files. Input data file names are given an extension of .DUI by the program. After completing all file-management operations, if any, select the option to continue. The program will display a reference screen with points of contact and then the DUMP Activity Selection Menu.

c. Activity selection menu. The activity selection menu may be considered the main menu for the DUMP application. The first option is used to analyze bulk-sediment and elutriate data for determining which specific contaminant should be selected for modeling (see step d). The second option is used to enter data and build, edit, or write input and execution data files (see step e). The third option executes the simulation and graphics (see step k), and the remaining options print or review output files and graphics (see step l).

d. Dilution Requirements for Initial Mixing Menu. A data-analysis routine controlled by this menu is used to select a specific contaminant for modeling. Such a selection is necessary under the Tier II analysis both for evaluation of the need for additional testing and for water-quality comparisons with criteria. Execution of the open-water disposal models for these Tier II analyses allow use of only one contaminant; this option is used to select that contaminant.

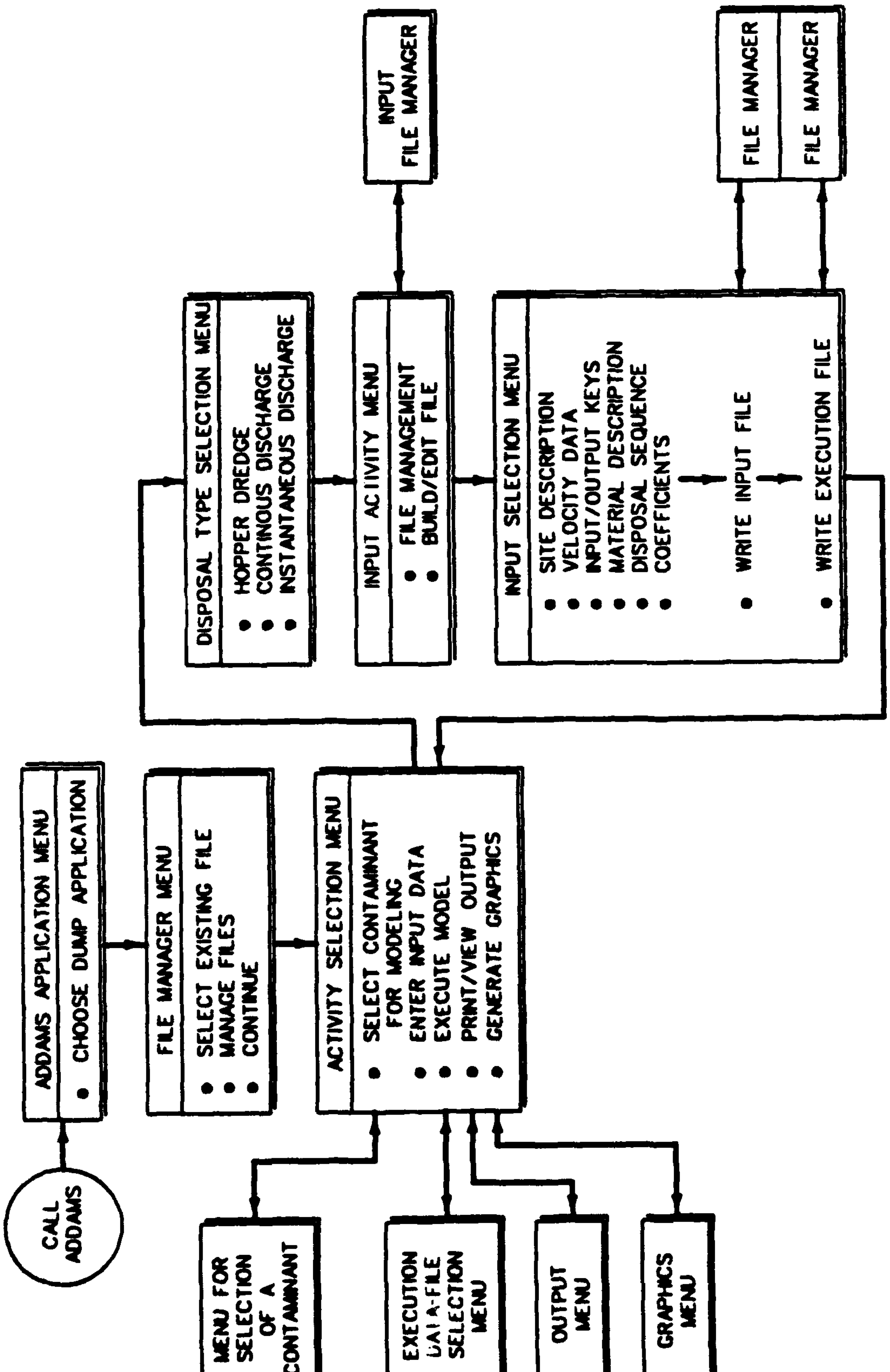

Figure B-1 Menu Tree for DUMP Model

Bulk sediment contaminant concentrations and WQC are required to compute the required dilutions for the evaluation of the need for additional testing. The contaminant requiring the largest dilution should be subsequently modeled.

Elutriate and background concentrations and WQC are required to compute the required dilutions for the analysis to compare dissolved contaminant concentrations with WQC. The contaminant requiring the largest dilution should be subsequently modeled.

e. Disposal-Type Selection Menu. The selection of a disposal type under this menu controls the input data requests, the type of execution data file that will be built, and the open-water disposal model that will be executed. Select the appropriate type of disposal: Disposal from a Hopper Dredge, Continuous Discharge from a Pipeline, or Instantaneous Dump from a Barge or Scow. The input data file last used by the program or selected earlier in step b will be read. If the file is new, the input data will be initialized. A DUMP Input Activity Selection Menu will then be displayed.

f. Input Activity Selection Menu. The first option is used to read a different input data file or initialize a new data file. This option will call the DUMP Input File Manager Menu to permit file selection (see step g for description). After selecting or initializing an input data file, if needed, select the second option to enter or edit input data and write input and execution data files. A DUMP Input Selection Menu will be displayed.

g. Activity File Manger Menu. A similar file manager is used for input, execution, or output data file selection and saving. The first option is used to specify the name of the file to be used (saved, read, viewed, plotted, or printed). The file specified in this option becomes the active data file. If needed, the second option is used to specify the DOS path to the location where the data file should be read or saved. The third option displays a directory of appropriate DUMP data files for the current path. An existing data file name may be selected from the list to use as the active data file name for overwriting or reading existing data. For example, one option may save the existing data in a file having the active data file name. The other options available are dependent on the routine (menu option) calling the file manager. The input data that are stored in files with an extension of .DUI are displayed in the input data screens displayed under this option. This option is used also to build execution data files. Execution data files are the actual input data files used by the open-water disposal model to perform the analysis and generate output. These files are unique in structure to the input requirements of a particular open-water disposal model, either DIFHD,

DIFCD or DIFID. The files are stored with an extension of .DUE. Other call/dependent options include starting the reading, viewing, or graphics.

h. Input Selection Menu. Five types of input data have to be entered, plus any desired changes in the default set of model coefficients, before an execution data file can be written. Default values are included for all of the model coefficients requested. An input data file may be written at any point to save all the data that have been entered up that point. Enter data by paging down through the data-entry screens and filling in the cells for each option.

i. Write input data file. Write an input data file to save the input data for future editing and use of the appropriate option under the DUMP Input Selection Menu. A DUMP Activity File Saving Menu will be displayed (see step g).

j. Write execution data file. Write an execution data file to save the input data in the data structure used by the selected open-water disposal model. The execution data file is the input used during execution of the simulation. This is performed by selecting the appropriate option on the DUMP Input Selection Menu. A DUMP Activity File Saving Menu will be displayed (see step g). All steps required for data entry or editing have been completed and the program is ready to execute the analysis.

k. Execute. Return to the DUMP Activity Selection Menu by repeatedly pressing the Esc key. Select the option to execute the open-water disposal model. This option uses an execution data file to generate an output file and graphics file of the same name as the execution data file selected but with an extension of .DUO and .DUP, respectively, instead of .DUE. An Execution Data File Selection Menu will be displayed that is similar to the file-manager menu described in step g. The only difference is that an option is provided to execute the disposal model instead of saving and writing the data file. The program will then execute the analysis using the selected execution data file and generate output and graphics files. Depending on the structure of the execution data file, either the DIFHD, DIFID, or DIFCD model will be executed. The execution may take a few minutes or several hours, depending on the simulation selected and the computer hardware used, but typically 30 min is sufficient. For long-term transport diffusion computations the DIFCD program may require about 5 times as long to run as the other disposal models.

l. Print, View, or Plot Results. To display the results, select the appropriate option on the DUMP Activity Selection Menu. A DUMP Output or Graphics Data File Selection Menu will be displayed that is similar to the file-manager menu described in step g. The only difference is that an option may be selected to display the output. The output has 132 characters per line and should be printed using compressed print or wide paper. The program will automatically use compressed print on some printers, mainly Epson and IBM printers. It may be necessary to turn on compressed printing on your printer prior to printing the output, or to print the output outside the ADDAMS program, using the DOS print command or a word processor. In addition, the DUMP Output Data File Selection Menu has an option to view the output using the LIST.COM utility program. Similar options are available to view graphic output. This step completes execution of the DUMP application.

m. Ending. To exit the program, press Esc repeatedly until you obtain a DOS prompt. During execution of a particular application's program, the user has to wait until the sometimes lengthy computations are computed. The program can also be terminated by a Control-Break or by turning off the computer, but loss of data may occur. These methods of ending are not recommended. Similar methods are available during printing of output.

B1.8 EXAMPLE APPLICATIONS

Three example applications are presented in this appendix. The examples illustrate the use of DIFID to evaluate for the need for additional water-column testing (Tier II), DIFCD for a comparison of dissolved contaminant concentrations with WQC (Tier II), and DIFHD for comparison of water-column concentrations of dredged material with bioassay results (Tier III). Descriptions of the examples and a discussion of the model results follow. The input and output files for each of the examples are saved on the diskettes in the pocket in the back of this manual.

B1.8.1 Example Application of DIFID

This example demonstrates the application of the instantaneous dump model DIFID and the evaluation of the need for additional water-column testing under Tier II. The input and output files for this example are named DIFID.DUI and DIFID.DUO, respectively.

B1.8.1.1 Operations Information

Disposal from a split hull barge at a disposal site with a constant water depth is modeled. The total volume of the dredged material is 1000 cu yd and is contained in a barge 100 ft long and 50 ft wide. The barge is stationary at the point of release. The unloaded draft of the barge is 5.0 ft, and the time required to empty the barge is 5.0 s.

B1.8.1.2 Disposal-Site Information

The disposal site is 6000 × 6000 ft. A 30 × 30 grid with a 1500-ft grid spacing was selected, with the disposal site centered in the grid. The total water depth is 100 ft and there is no bottom slope. The ambient water current is 2.0 ft/s, directed from south to north for the upper 40 ft of the water column. The current then reverses direction over the next 20 ft to become 2.0 ft/s, directed from north to south at a depth of 60 ft below the surface. A linear decrease to a value of zero at the bottom follows. The ambient density profile is a constant 1.018 g/c^3 from the surface to depth of 40 ft, increasing to 1.022 g/c^3 at a depth of 60 ft, and a constant of 1.022 g/c^3 to the bottom.

B1.8.1.3 Dredged-Material Information

The dredged material is composed of a sand and a silty-clay solid fraction. The sand volumetric concentration is 0.14 ft^3/ft^3 and silty-clay volumetric concentration is 0.17 ft^3/ft^3. The remaining 0.69 ft^3/ft^3 is composed of water (both void spaces and entrained water). The settling velocity of the sand is taken to be 0.07 ft/s, whereas the silty-clay fraction is treated as a cohesive fraction with the settling velocity internally computed. Following deposition on the bottom, a void ratio of 4.0 is specified for the silty-clay fraction, whereas a void ratio of 0.8 is specified for the sand. The required dilutions of all contaminants of concern to meet their respective WQC were computed. Cadmium was found to be the contaminant of concern, requiring the highest dilution to meet its WQC, and was selected as the parameter to be modeled for evaluation of the need for additional water-column testing. The sediment concentration for cadmium is 20 mg/kg and the acute marine WQC for cadmium is 0.043 mg/L .

B1.8.1.4 Coefficients

Default values were used for all coefficients.

B1.8.1.5 Controls for Execution and Output

The total simulation time is specified as 4 h or 14,400 s, with a 600-s computational time step. Output is specified for depths of 10, 50, and 99 ft, which correspond to near surface, mid-depth and near bottom, respectively.

B1.8.1.6 Summary of Output

As can be seen from the output, the disposal cloud strikes the bottom in 7.19 s and grows from an initial radius of 23.44 ft to a final radius at the bottom encounter of 47.58 ft. Collapse on the bottom then occurs, with the collapse phase terminated at 32.62 s after the disposal, with the final cloud having a diameter of 1234.98 ft. During the initial-mixing period of 4 h, the calculated maximum concentration of cadmium outside the disposal-site boundary is 0.000682 mg/L, occurring 40 min after disposal at a depth of 50 ft. This concentration is less than the acute WQC of 0.043 mg/L. Therefore, there is no need for additional water-column testing according to the guidance in Sections 10.1.1 and 5.1.

B1.8.2 Example Application of DIFCD

This example demonstrates the application of the continuous-discharge model DIFCD and the comparison of dissolved contaminant concentrations with WQC under Tier II. The input and output files for this example are named DIFCD.DUI and DIFCD.DUO, respectively.

B1.8.2.1 Operations Information

A pipeline disposal operation from a stationary barge at a disposal site with constant water depth of 50 ft is modeled. The pipeline is 1.0 ft in diameter with a discharge rate of 5 ft^3/s for 3600 s. The end of the pipe is located at a water depth 10 ft below the surface at an angle of 90° with respect to the water surface.

B1.8.2.2 Disposal-Site Information

The disposal site is 3000 × 3000 ft. A 30 × 30 grid with a 250-ft grid spacing was selected. The disposal site is located within one corner at a distance of 2250 ft from the northern edge of the grid and 500 ft from the western edge of the grid and with the opposite corner 5250 ft from the northern edge of the grid and 3500 ft from the western edge of the grid. The discharge point is located 4000 ft from the northern edge of the grid and 1500 ft from the western edge of the grid. The disposal site is a constant-depth site of 50 ft. The ambient-water current is directed from west to east, with a magnitude of 0.5 ft/s over the upper 45 ft of the water column. The velocity then linearly decreases to 0.25 ft/s at 1 ft above the bottom and finally to zero at the bottom. The ambient density is assumed to vary linearly from 1.0 g/c^3 at the surface to 1.010 g/c^3 at the bottom.

B1.8.2.3 Dredged-Material Information

The dredged material is a slurry with an average bulk density of 1.32 g/c^3 and is composed of two solid fractions, sand and silt. The concentration of each is 0.10 ft^3/ft^3. The settling velocity is 0.07 ft/s for sand and 0.02 ft/s for silt. The void ratio after bottom deposition is 3.0 for silt and 0.8 for sand. A previous evaluation indicated a need to conduct additional water-column testing. Tests were performed to determine initial dissolved contaminant concentrations in the water column under Tier II. The required dilutions of all contaminants of concern to meet their respective WQC were computed. Cadmium was found to require the highest dilution and was selected as the parameter to be modeled and compared with its WQC. The initial water-column concentration of dissolved cadmium was determined to be 0.9 mg/L, the background concentration for cadmium was 0.001 mg/L, and the acute marine WQC for cadmium is 0.043 mg/L.

B1.8.2.4 Coefficients

Default values were used for all coefficients.

B1.8.2.5 Controls for Execution and Output

The total simulation time is specified as 4 h or 14,400 s, with a 900-s computational time step. Output is specified for depths of 30 and 49 ft, which correspond to middepth and near bottom, respectively.

B1.8.2.6 Summary of Output

As indicated in the output, the momentum jet strikes the bottom after 10.29 s, with a radius of 4.496 ft. Collapse on the bottom terminates after 29.66 s. The calculated maximum concentration of cadmium after the 4-h initial-mixing period is 0.000013 mg/L above background, and the maximum concentration of cadmium outside the disposal site boundary during the 4-h initial-mixing period is 0.0002 mg/L above background. Both of these values are less than the WQC of 0.043 mg/L, and are acceptable according to the guidance in Sections 10.1.2.3 and 5.1.2.

B1.8.3 Example Application of DIFHD

This example demonstrates the application of the hopper-dredge model DIFHD and the comparison of water-column concentrations of dredged material with water-column bioassay results under Tier III. The input and output files for this example are named DIFHD.DUI and DIFHD.DUO, respectively.

B1.8.3.1 Operations Information

A disposal operation is modeled from a stationary hopper dredge containing eight bins configured in four pairs of two bins, with pairs of bins opened sequentially. Disposal is assumed to occur from pairs of bins with the disposal from one pair essential complete before the disposal from the next pair begins. The total discharge takes 120 s and occurs through bin doors with a cross-sectional area of 16 ft^2, which yields an equivalent circular geometry with a radius of 2.26 ft. The centerline distance between the bins is 14 ft. The loaded draft is 10 ft. The discharge rate from each bin is taken to be 75 ft^3/s.

B1.8.3.2 Disposal-Site Information

The disposal site is 5250 $\times$ 5250 ft. A 30 $\times$ 30 grid with a 750-ft grid spacing was selected. The disposal site is located within the grid with one corner at a distance of 8250 ft from the northern edge of the grid and 2250 ft from the western edge of the grid and with the opposite corner 13,500 ft from the northern edge of the grid and 7500 ft from the western edge of the grid. The location of the hopper dredge is 4500 ft from the western edge of the grid and 11,250 ft from

the northern edge of the grid. The disposal site is a constant depth site with a water depth of 75 ft and no bottom slope. The ambient current is 0.9 ft/s over the upper 70 ft of the water column and is directed from west to east. The velocity then decreases linearly over the next 4 ft to 0.2 ft/s, then linearly over the next foot to zero. The ambient density is 1.00 g/c^3 at the surface and increases linearly to 1.01 g/c^3 at the bottom.

B1.8.3.3 Dredged-Material Information

The dredged material is composed of sand and clay solid fractions, each having a concentration of 0.10 ft^3/ft^3. The setting velocity of the sand is 0.07 ft/s while the clay is considered cohesive with the settling velocity computed internally. The void ratio on deposition is 4.0 for the clay and 0.8 for the sand. The model is used to estimate the concentrations of dissolved plus suspended dredged-material constituents in the water column expressed as a percent of the initial concentration. Water-column bioassays indicated that the LC_{50} was 30% of the original dredged-material concentration.

B1.8.3.4 Coefficients

Default values were used for all coefficients.

B1.8.3.5 Controls for Execution and Output

The total simulation time is specified as 4 h or 14,400 s, with a 600-s computational time step. Output is specified for depths of 50 and 74 ft, which correspond to near middepth and near bottom, respectively.

B1.8.3.6 Coefficients

Default values were used for all coefficients.

B1.8.3.7 Summary of Output

As can be seen from the output, the jet of material from a bin reaches the bottom after 9.72 s and has a radius of 7.23 ft. The resulting bottom collapse continues as long as the bottom

cloud is fed by the continuous discharge of material from the remaining bins. The maximum concentration of suspended plus dissolved constituents of the dredged material after 4 h is 0.0008% of the original concentration, and the maximum concentration outside the disposal site boundary during the 4-h initial-mixing period is 0.0113% of original occurring 80 min after disposal at a depth of 74 ft. Both of these values are below 0.3% (0.01 of the LC_{50}); therefore the discharge is acceptable according to the guidance in Section 11.1.7.

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